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US ARMY

TEST & EVALUATION COMMAND

AD A030312

FINAL

REPORT OF

MILITARY POTENTIAL TEST

(COMPARATIVE EVALUATION)

OF

AUTOMATIC DIRECTION FINDING EQUIPMENT

DA PROJECT NO. 1G641203D526

USATECOM PROJECT NO. 4-4-4316-01

4 FEB 1965

J.E. Mallory
USAADTA (PROV)
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~~US ARMY~~

AVIATION TEST BOARD

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UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36362

9 FINAL rept. 1 Oct-15 Dec 64.

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USATECOM [redacted] 4-4-4316-Ø1

A. J. RANKIN
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ABSTRACT

The US Army Aviation Test Board (USAAVNTBD), US Army Electronic Proving Ground (USAEPG), and US Army Human Engineering Laboratory (USAHEL) conducted the Military Potential Test of the Automatic Direction Finding Equipment in the vicinities of Fort Rucker, Alabama, and Fort Huachuca, Arizona, during the period 1 October 1964 through 15 December 1964. The US Army Aviation Test Activity (USAATA) was also a participating test agency. It was found that all of the sets met the technical criteria with regard to weight, but Salmon exceeded the volume limits by two percent. Salmon performed better than the others in flight; Aqua performed satisfactorily; Maroon was noisy, had low sensitivity on "loop," and was unusable during thunderstorm activity. None of the sets met all of the SCL and TSO requirements. Technical requirements were inadequate. No unusual maintenance problems were experienced. Tool Kits TK-87/U and TK-88/U were adequate for organizational and field maintenance; however, some special test equipment would be required. Aqua had four deficiencies, Maroon had eight, and Salmon had four. Salmon was ranked first in the composite Human Engineering Tests with Aqua second and Maroon third. It was concluded that Salmon is the most promising and suitable system for Army use, Aqua the next most suitable, and Maroon the least suitable; that the deficiencies must be corrected before any system is acceptable for Army use; that available technical requirements we[illegible]t a satisfactory standard for technical evaluation of these systems; an[illegible] correction of shortcomings would enhance the suitability of each sys[illegible] f[illegible] rmy use. It was recommended that the deficiencies be correcte[illegible] [illegible]or to acceptance of any system; the system selected undergo a complete engineering/service test prior to acceptance as a standard item; and the technical requirements be rewritten prior to engineering/service test.

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UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36362

REPORT OF TEST

USATECOM PROJECT NO. 4-4-4316-01

MILITARY POTENTIAL TEST (COMPARATIVE EVALUATION) OF

AUTOMATIC DIRECTION FINDING EQUIPMENT

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SECTION 1 - GENERAL

1.1. REFERENCES.

a. Report of Test, Project No. AVN 6356, "Comparative Evaluation of Automatic Direction Finding Equipment," US Army Aviation Board, April 1957.

b. Technical Manual TM 11-5826-204-35, Department of Army, 12 September 1958.

c. ARINC Characteristic No. 550, "Airborne ADF System Mark-2," Aeronautical Radio, Inc., 1 March 1962.

d. Technical Manual TM 11-2557-25, Department of Army, Third Edition, May 1963.

e. Technical Manual TM 11-5826-204-12, Department of Army, 30 September 1963.

f. Letter, Assistant Secretary of the Army (ASA), Installation and Logistics (Mr. Ignatius), 13 November 1963, subject: "FY 64 Procurement of Avionics Equipment," with four indorsements thereto.

g. Memorandum for Record, STEBG-TPAV, US Army Aviation Test Board, 15 April 1964, subject: "Test Requirements Conference, Military Potential (Comparative Evaluation) Test of the OMNI, ADF, and HF Radios, USATECOM Project No's. 4-4-4315/4316/4317."

h. Memorandum for Record, STEBG-TPAV, US Army Aviation Test Board, 29 April 1964, subject: "USAECOM/USATECOM Planning Conference for Military Potential Test of OMNI, ADF, and HF Radios, USATECOM Project No's. 4-4-4315/4316/4317."

i. Message, AMSEL-RD-SRI-5-27, US Army Electronics Command, 6 May 1964, subject: "Confirming Telephone Message to Major Treece on 1 May 1964 Regarding Military Potential Test of OMNI and ADF Receivers."

j. Letter, SELMA-M5e-4, US Army Electronics Command, 16 May 1964, subject: "Solicitation No. AMC(E)26-039-64-430-8 (Step I) (Invitation for Bid) (IFB)."

k. Plan of Test, USATECOM Project No. 4-4-4316-01, "Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment," US Army Aviation Test Board, 15 June 1964.

l. Technical Requirements:

(1) Signal Corps Letter (SCL) 8012B, "Direction Finder, Automatic Lightweight, Airborne," US Army Electronics Command, 10 July 1964, with Amendment No. 1, dated 7 August 1964.

(2) Federal Aviation Agency (FAA) Technical Standard Order (TSO) C41.

m. Paper 158-61/DO-111, "Minimum Performance Standards Airborne Radio Receiving and Direction Finding Equipment Operating within the Frequency Range of 200-415 Kilocycles," Radio Technical Commission for Aeronautics, 10 August 1961.

n. Paper 120-61/DO-108, "Environment Test Procedures, Airborne Electronic Equipment," Radio Technical Commission for Aeronautics.

1.2. AUTHORITY.

1.2.1. Directive.

1.2.1.1. Letter, AMSEL-AV-E, Headquarters, US Army Electronics Command, 24 February 1964, subject: "Modernization Program for OMNI-Range Receivers, Automatic Direction Finding Equipment and Lightweight HF Aircraft Radio Sets," with one inclosure.

1.2.1.2. Letter, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 17 March 1964, subject: "Test Directive, USATECOM Project No. 4-4-4316-( ) Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment."

1.2.1.3. Letter, AMSTE-BG, US Army Test and Evaluation Command 22 May 1964, subject: "Supplement Test Directive, USATECOM Project No. 4-4-4316-( ), Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment."

1.2.2. Purpose.

To compile sufficient test data which may b. used as a basis for selection of the most promising or suitable Auto.natic Direction Finding (ADF) System or Systems for Army use.

1.3. OBJECTIVES.

To determine of each ADF system its:

a. Physical characteristics.

b. Performance in flight.

c. Technical suitability.

d. Maintenance and support requirements.

e. Deficiencies which would preclude Army acceptance of the equipment.

f. Human engineering characteristics.

1.4. RESPONSIBILITIES.

1.4.1. US Army Aviation Test Board.

The US Army Aviation Test Board (USAAVNTBD), as the executive test agency, was responsible for the following:

a. Reviewing specifications and available data to determine the tests required to evaluate the ADF's.

b. Conducting such tests and tasks as required to establish the degree to which each system meets Army requirements.

c. Preparing and publishing the plan of test and the report of test.

1.4.2. US Army Electronics Proving Ground.

The US Army Electronics Proving Ground (USAEPG) as a participating test agency (PTA) was responsible for the following:

a. Reviewing available engineering test data concerning the equipment to determine the engineering tests required to evaluate the ADF's.

b. Conducting engineering tests as required.

c. Assisting in preparation of test plan and report.

1.4.3. US Army Aviation Test Activity.

The US Army Aviation Test Activity (USAATA), as a PTA, was responsible for the following:

a. Reviewing specifications and available test data to determine the flight testing needed to qualify equipment.

b. If required, conducting flight tests to establish performance and airworthiness.

c. Assisting in preparation of test plan and report.

1.4.4. US Army Human Engineering Laboratory.

The US Army Human Engineering Laboratory (USAHEL), as a PTA, was responsible for the following:

a. Reviewing specifications and available test data to determine testing necessary to evaluate man-machine compatibility.

b. Conducting tests as required.

c. Assisting in preparation of test plan and report.

1.5. DESCRIPTION OF MATERIEL.

1.5.1. The ADF system is a lightweight airborne navigation aid that automatically provides a visual indication of relative bearing of a radio transmitter with respect to the aircraft. The following modes of operation are provided:

a. ADF Compass--Automatically provides visual relative-bearing indications of a selected radio transmitter with respect to the aircraft.

b. Loop--Provides visual relative-bearing indications of a selected radio transmitter by manual operation of a control located on the radio control unit to null the received signal.

c. Antenna--Used for radio range or as a general radio receiver.

1.5.2. For purposes of this report, the code names of Aqua, Maroon, and Salmon have been assigned to the ADF systems provided by the three manufacturers. A key to this code is provided separately. The following are brief descriptions of each individual ADF evaluated (detailed descriptions are contained in appendix III, section 4):

1.5.2.1. Aqua. Aqua frequency coverage was 190 kc. to 1750 kc. on three bands. The system, less cables, weighed 14 pounds and 7 ounces and consisted of six major components (figure 1):

a. ADF Tuner.

b. ADF Amplifier.

c. ADF Gonio/Indicator.

d. ADF Loop Antenna.

e. ADF Antenna Coupler.

f. Mountings.

1.5.2.2. Maroon. Maroon frequency coverage was 100 kc. to 3,000 kc. on four bands. The system, less cables, weighed 18 pounds and 13 ounces and consisted of five major components (figure 2):

a. Radio Receiver.

b. Synchro Signal Amplifier.

c. ADF Indicator.

d. ADF Loop Antenna.

e. Mountings.

1.5.2.3. Salmon. The Salmon frequency coverage was 190 kc. to 1750 kc. on three bands. The system, less cables, weighed 18 pounds and 4 ounces and consisted of six major components (figure 3):

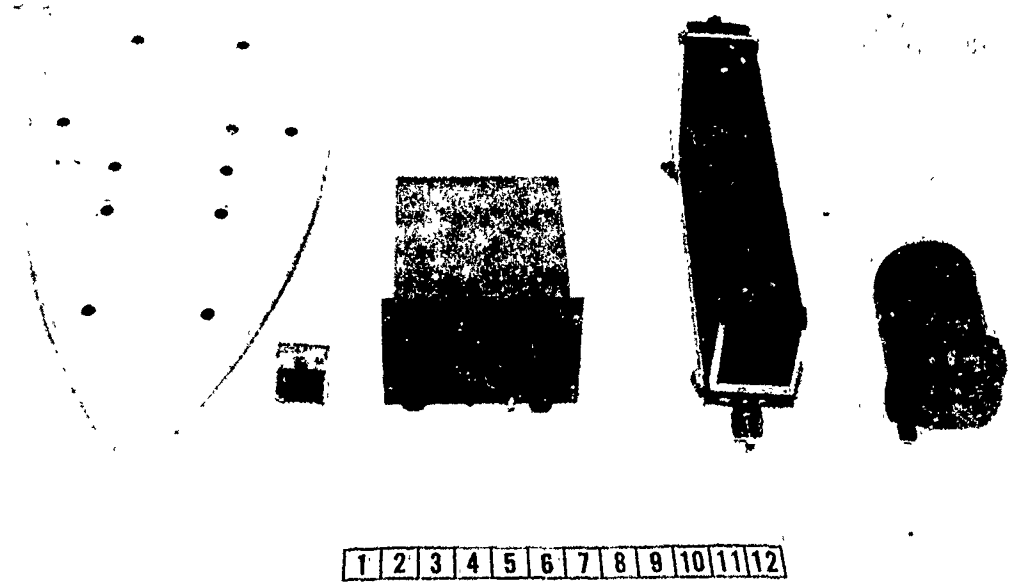


Figure 1. Components of the Aqua System (Left to right: ADF Loop Antenna, ADF Antenna Coupler, ADF Tuner, ADF Amplifier (in mount), ADF Gonio/Indicator)

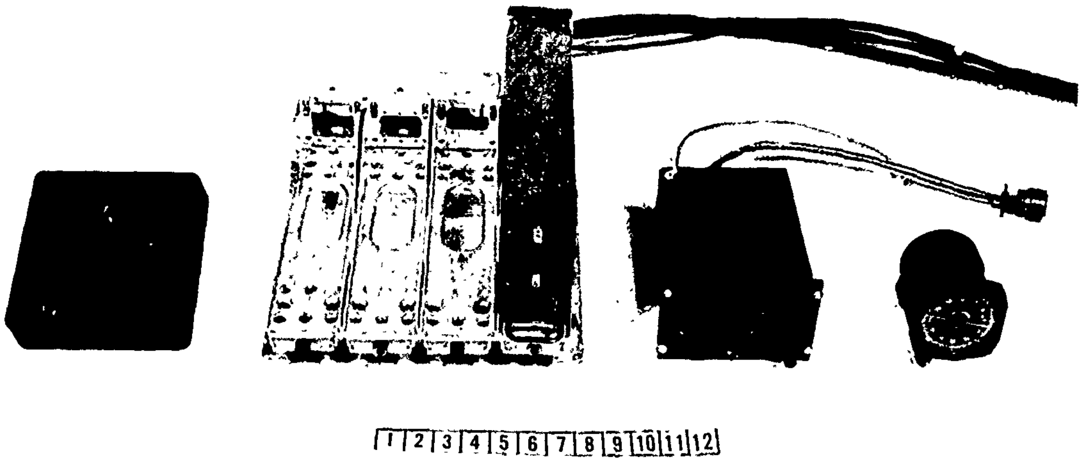


Figure 2. Components of the Maroon System (Left to right: ADF Loop Antenna, Synchro Signal Amplifier (in mount), Radio Receiver, ADF Indicator)

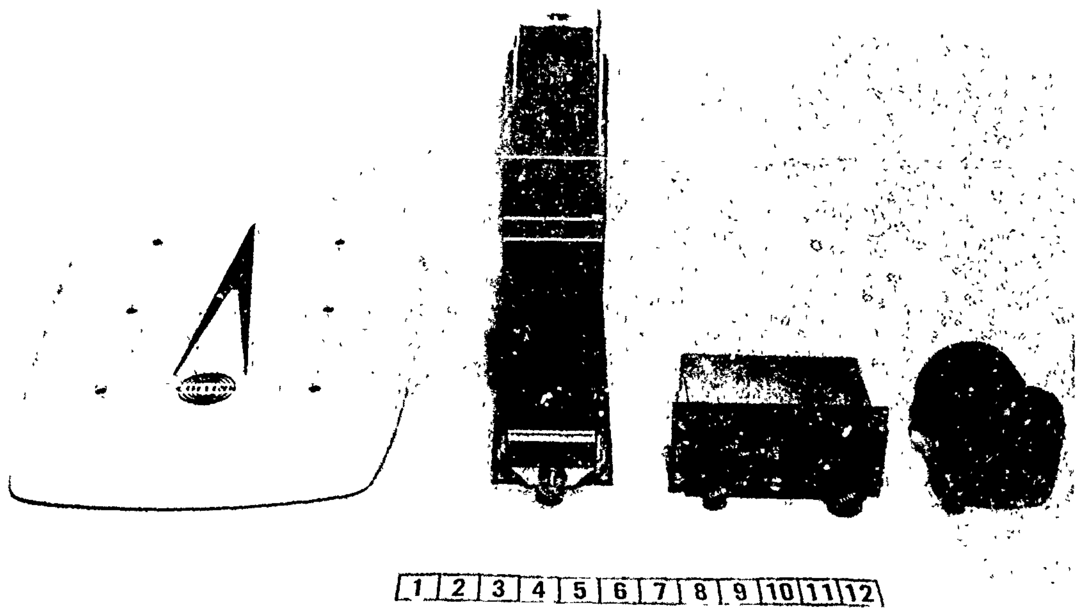


Figure 3. Components of the Salmon System (Left to right: ADF Loop Antenna, ADF Receiver (in mount), ADF Control Unit, ADF Bearing Indicator. Not shown: ADF Sense Antenna Coupler)

a. ADF Control Unit.

b. ADF Receiver.

c. ADF Bearing Indicator.

d. ADF Loop Antenna.

e. ADF Sense Antenna Coupler.

f. Mountings.

1.6. BACKGROUND.

1.6.1. As a result of a comparative evaluation of five ADF's in April 1957 (reference a), the AN/ARN-59 was found most suitable and adopted as standard Army equipment in July 1957. This equipment has been procured from a sole source for seven years.

1.6.2. In the interest of obtaining the most modern equipment for the Army, the Assistant Secretary of the Army (Installations and Logistics) has directed (reference c) that a comparative evaluation be made of available off-the-shelf ADF equipment.

1.6.3. Conferences were held at Fort Rucker, Alabama, in April 1964 (reference e) with representatives from US Army Test and Evaluation Command (USATECOM), US Army Electronics Command (USAECOM), US Army Electronics Research and Developments Laboratory (USAELRDL), USAEPG, and USAAVNTBD. These conferences established the general guidance for planning the ADF tests to be conducted by USATECOM agencies for USAECOM. The USAECOM selected the items to be tested.

1.6.4. In May 1964, USAECOM asked industry to propose "off-the-shelf" systems for military potential testing. Three ADF systems of different design were selected for evaluation. The evaluation began on 1 October 1964.

1.6.5. Reports of ADF evaluation previously conducted were researched and pertinent information was used in conducting this test. Quantitative data upon which to gauge progress in this field are not available.

1.7. FINDINGS.

1.7.1. Physical Characteristics.

All the sets met the technical criteria with regard to weight. Salmon exceeded the volume limits by two percent.

1.7.2. Performance in Flight.

Salmon performed appreciably better in flight than the other two sets. Average maximum range of Salmon was one-third greater than that of the other equipments. Aqua performed satisfactorily in flight. Maroon was noisy and had low sensitivity on "loop," and was unusable during thunderstorm activity.

1.7.3. Technical Suitability.

Tests to determine technical suitability were conducted at USAEPG. A summary of their findings is as follows (for complete report, see part A, section 3):

1.7.3.1. None of the sets met all of the SCL and TSO requirements.

1.7.3.2. There were no equipment deficiencies and only one shortcoming observed during the technical evaluation at USAEPG.

1.7.3.3. Technical requirements were inadequate in some of the following areas:

1.7.3.3.1. There were no criteria for safety or allowable warm-up time.

1.7.3.3.2. In some cases criteria were established for items which are not necessary or feasible for the equipment, such as a fail-safe device.

1.7.3.3.3. Criteria were given specifying output loads and output powers which were based on the characteristics of the AN/ARN-59 and which should have been altered for this test.

1.7.4. Maintenance and Support Requirements.

No unusual maintenance problems were experienced. None of the sets gave any special problems in maintenance or support during this evaluation. Special training was not required for operation or organizational maintenance of any system. Tool Kits TK-87/U and TK-88/U were adequate for organizational and field maintenance for each system. However, some special test equipment would be required for each of the systems.

1.7.5. Deficiencies Which Would Preclude Army Acceptance of the Equipment.

1.7.5.1. Deficiencies are as follows:

1.7.5.1.1. Aqua.

On the ADF tuner control panel, the toggle switches for loop and for BFO (Beat Frequency Oscillator) control were too small, and the index line on the frequency dial was difficult to see at night.

Speech intelligibility was below the "normal" category.

1.7.5.1.2. Maroon.

On the radio receiver control panel, the toggle switches for loop and BFO control were too small; the frequency dial was masked due to small size of the window; the tuning meter was too small and was partially masked; and the digital frequency readout did not align accurately with the selected frequency.

Speech intelligibility was below the "normal" category.

Receiver sensitivity was too low.

The loop antenna did not meet the Federal Aviation Agency (FAA) TSO applicable in the area of loop antenna sensitivity. This resulted in a degradation of performance in flight, especially in "loop" mode.

1.7.5.1.3. Salmon.

On the ADF control unit, the frequency dial index markings were non-linear and were marked in megacycles rather than kilocycles; the BFO switch was too small, and knob markings were not illuminated.

1.7.5.2. Deficiencies and shortcomings are listed in appendix II, section 4.

1.7.6. Human Engineering Characteristics. Salmon was ranked number one in the composite Human Engineering tests, and was scored "normal." Both the other systems were scored "below normal" with Aqua ranked second and Maroon third.

1.8. CONCLUSIONS.

1.8.1. Salmon is the most promising and suitable system for Army use; Aqua is the next most suitable system; and Maroon is the least suitable system.

1.8.2. Correction of deficiencies listed in appendix II, section 4, must be accomplished before any of the systems is acceptable for Army use.

1.8.3. Available technical requirements were not a satisfactory standard for technical evaluation of these systems.

1.8.4. Correction of shortcomings listed in appendix II, section 4, would enhance the suitability of each system for Army use.

1.9. RECOMMENDATIONS. It is recommended that:

1.9.1. The deficiencies listed in appendix II, section 4, be corrected prior to acceptance of any system.

1.9.2. The system selected be subjected to a complete engineering/service test prior to acceptance by the US Army as a standard item.

1.9.3. The technical requirements be rewritten prior to engineering/service test of the selected system to provide clear, realistic specifications in keeping with the state of the art in navigation equipment.

SECTION 2

DETAILS AND RESULTS OF SUBTESTS

SECTION 2 - DETAILS AND RESULTS OF SUBTESTS

2.0. INTRODUCTION.

2.0.1. The ADF Receiver Systems were tested by the US Army Aviation Test Board (USAAVNTBD), US Army Electronic Proving Ground (USAEPG), and US Army Human Engineering Laboratory (USAHEL), during the period 1 October 1964 through 15 December 1964. Because of the competitive nature of this evaluation, every effort was made by test personnel to insure fair and equal treatment of each system. Operational testing and human engineering evaluations were performed in the vicinity of Fort Rucker, Alabama. Technical evaluations were performed at Fort Huachuca, Arizona.

2.0.2. The test systems were installed in both rotary-wing (JUH-19D) and fixed-wing (RU-8D) aircraft by the manufacturers' representatives and calibrated and released by them prior to flight test. The test systems were operated in flight by pilots whose flying experience ranged from less than 1,000 hours to more than 10,000 hours. Operating time in excess of 230 hours was logged for each system. A total of 806 hours of equipment operating time was accumulated during this evaluation.

2.0.3. Each system was tested against the SCL-8012B with Amendment No. 1, dated 12 August 1964. In accordance with reference 1.1.c. (Amendment 5, paragraph e), the following alternate standard was used: When a test item failed to meet the SCL-8012B with Amendment No. 1, and an appropriate TSO existed, the test item was tested against the TSO.

2.0.4. The technical evaluation, accomplished at Fort Huachuca, Arizona, by USAEPG, encompassed bench tests to determine the ability of the test systems to fulfill the Technical Requirements imposed on them for test.

2.0.5. All maintenance was performed by maintenance personnel assigned to the respective test activities with technical assistance provided by each manufacturer.

2.0.6. Overlap of certain aspects of the evaluation resulted in some redundancy of tests and reports by the respective test agencies. For example, physical characteristics, technical suitability, maintenance and support requirements, deficiencies and human factors were of interest to

the USAAVNTBD, USAEPG, and USAHEL. Performance in flight was of interest to the USAAVNTBD and USAHEL. In these overlapping areas, every effort was made to minimize repetition throughout this report.

2.1. PHYSICAL CHARACTERISTICS.

2.1.1. Objective.

To determine the physical characteristics of the ADF receiver systems.

2.1.2. Method.

2.1.2.1. Components were examined, weighed, measured, and photographed. The dimensions and weight of each component were determined, and the total volume and weight of the system were calculated and compared with those specified in the Technical Requirements.

2.1.2.2. Components were examined for unusual physical features that add to or detract from the system suitability. Attention was directed to design and location of controls, indicators, lighting, and readouts.

2.1.2.3. Representative samplings were recorded of the time required for those functions that could be measured, such as time for system to warm up and reach satisfactory operating conditions.

2.1.2.4. The instructions, drawings, and diagrams and the installation were examined for adequacy, completeness, and any unusual requirements.

2.1.2.5. The size of skin cuts for antenna mountings and the structure projecting into the air stream were determined and compared for all test systems.

2.1.3. Results.

2.1.3.1. The dimensions and weights for each system are shown in table II of USAEPG report, section 3.

2.1.3.2. A complete report on physical features such as design and location of controls, indicators, lighting, and readouts is shown in USAEPG and USAHEL reports, section 3.

2.1.3.3. The warm-up times are shown in USAEPG report, section 3.

2.1.3.4. Installations were made by manufacturers' representatives. There were no difficulties with any of the installations. Instructions, drawings, and diagrams furnished were adequate.

2.1.3.5. Size of skin cuts and projecting structures was as follows:

2.1.3.5.1. Aqua required a 2.31-inch diameter hole and six mounting holes of 0.1695-inch in diameter. The antenna protruded 0.92 inch and was 9.875 inches wide for a frontal area of 9.08 square inches.

2.1.3.5.2. Maroon required a 2.166-inch diameter hole and a 0.5625-inch diameter hole for the guide pin. The antenna protruded 1.6875 inches and was 6.25 inches wide for a frontal area of 10.56 square inches.

2.1.3.5.3. Salmon required a 1.4375-inch diameter hole and six mounting holes of 0.187-inch in diameter. The antenna protruded 0.875 inch and was 12 inches wide for a frontal area of 10.50 square inches.

2.1.4. Analysis.

2.1.4.1. All of the systems met the technical criteria with regard to weight. Salmon exceeded the volume limit of 750 cubic inches by 2 percent.

2.1.4.2. The frontal area of all three systems was comparable. The skin cuts required were comparable.

2.1.4.3. All control panels and heading displays had some deficiencies and shortcomings. From a human engineering standpoint, Salmon was the most suitable, and Maroon was the least suitable in this area.

2.2. PERFORMANCE IN FLIGHT.

2.2.1. Objective.

To determine the performance of the ADF equipment when operating in flight (paragraph 2, appendix II).

2.2.2. Method.

Accuracy for track following, intersection, holding, and low approach and the maximum operating ranges were determined by repeating each of these tests for the test systems a sufficient number of times to obtain data for subsequent plotting and measurement. Known ground locations were utilized where appropriate, along with other standard position-fixing methods such as intersecting OMNI-radials. The aircraft position over check points was determined visually. Each aircraft compass was calibrated prior to commencement of the tests, and upon completion of the tests. Records of these calibrations were maintained. The test systems were flown by pilots of the USAAVNTBD and the USAAVNS. Flights were planned, following standardized profiles. The comments of all pilots were recorded as a part of each test flight.

2.2.2.1. Maximum Usable Range. The test-bed aircraft were flown along selected ground tracks (separated by at least 60 degrees) from various low-frequency (LF) and medium-frequency (MF) ground stations to determine the maximum usable reception range of the ADF equipment. Excessive bearing-indicator needle oscillation, failure of the bearing indicator to return to the bearing position after being intentionally deflected, or loss of aural signal was used to determine maximum usable range. Simultaneous range tests were conducted in all test-bed aircraft to insure that each test item was subjected to the same atmospheric and ground station conditions. Quality of the aural signal and fluctuations of the bearing indicator were recorded at frequent intervals. The flights were conducted at or below minimum enroute altitudes published by the Federal Aviation Agency (FAA).

2.2.2.2. Track Following and Homing. All test-bed aircraft were flown over selected ground tracks to and from LF ground stations to determine the test item's capability for track following. A minimum of four ground tracks (inbound and outbound) were flown for each ground station selected. Difficulties in tracking attributable to the equipment were noted. Checks were made of station passage, time required for station passage indication, hunting of the bearing indicator, and unusual equipment performance. Flights of all test systems were conducted at altitudes of 1,000 feet to 3,000 feet above the terrain. All test-bed aircraft were flown on homing runs to LF ground stations. Each of these runs was separated by at least 60 degrees. The ability of the test item to direct the aircraft to a homing facility was determined.

2.2.2.3. ADF and Manual-Loop Orientation; Time and Distance Calculations. The test-bed aircraft were flown at altitudes from 1,000 feet absolute to 11,000 feet absolute to determine the operation of the test item when performing time and distance calculations, ADF orientation, manual-loop orientation, station identification, and voice reception. Station identification and voice reception were checked to determine clarity, tone, and freedom of interference. The effect of volume adjustment on null width and overall operation in the loop mode was recorded. The narrowing and then the definite widening of the null as the station was passed, and the definite move of the null away from the nose of the aircraft, were checked.

2.2.2.4. ADF and Manual Loop Approaches. Radio compass approaches were executed using manual and automatic modes of operation of the test systems. These tests were to determine the capability of the test systems to position the aircraft along a selected ground track for low approaches. Oscillation and erroneous needle reversals were recorded.

2.2.2.5. Effects of Meterological Conditions. The test-bed aircraft were flown during the hours of daylight and darkness and in all available weather conditions, to determine the effects of the meterological conditions on the performance of the test systems. The test systems were utilized for track following, homing, holding, intersection identification, station passage and approaches during the above conditions.

2.2.2.6. Electronic Interference. The test systems were operated in various combinations with other electronic equipment installed in the test-bed aircraft while in flight to check for interference between the test system and standard electronic equipment. Dual test systems were installed to determine their ability to operate from one test-bed aircraft and to determine whether mutual interference would result.

2.2.2.7. Helicopter Sling Loads. A flight check was made of the helicopter test bed with a sling load to determine the effect of external loads on the operation of the test systems and on the navigation information presented to the pilot by the test system.

2.2.2.8. Fail-Safe Function. None of the systems had a fail-safe function; therefore, evaluation of this device is not applicable.

2.2.3. Results.

2.2.3.1. Maximum Usable Range. Salmon had an average maximum usable range of 87 nautical miles, and Aqua and Maroon 63 miles, in the "Compass" mode.

2.2.3.2. Track Following and Homing.

2.2.3.2.1. All systems functioned satisfactorily during track following and homing in clear weather. Salmon's greater range enabled that system to track or home on stations one-third more distant than was possible with either Aqua or Maroon. Maroon was rendered unusable as an enroute navigation aid during thunderstorm activity; Aqua and Salmon continued to operate satisfactorily under these conditions.

2.2.3.2.2. All systems gave normal station passage indication.

2.2.3.2.3. No hunting of the bearing indicator or unusual equipment performance was noted except as stated in paragraph 2.2.3.2.1. above.

2.2.3.3. ADF and Loop Orientation; Time and Distance Calculation.

2.2.3.3.1. All systems functioned satisfactorily during station identification, ADF orientation, and time-distance calculations except as noted in paragraph 2.2.3.5.

2.2.3.3.2. Salmon's performance was adequate during loop orientation. Aqua performed adequately in this mode; however, its slew rate on manual loop was too fast and caused some operator difficulty. Maroon was difficult to use in manual loop mode due to excessive noise.

2.2.3.4. ADF and Manual Loop Approaches.

2.2.3.4.1. All systems functioned satisfactorily during ADF approaches.

2.2.3.4.2. Salmon functioned satisfactorily during manual loop approaches. Aqua and Maroon had excessive noise on "loop" position, and Aqua's slew rate on manual loop was too fast.

2.2.3.5. Effects of Meterological Conditions. Aqua and Salmon were not adversely affected by meterological conditions encountered during flight. Maroon's bearing indicator was deflected away from the station

during thunderstorm activity to such an extent that the system was not usable.

2.2.3.6. Electronic Interference.

2.2.3.6.1. Aqua and Salmon experienced no problems from electronic interference.

2.2.3.6.2. Maroon had background noise, including continuous wave (CW) and radio teletype (RTTY) signals, across the dial in all bands. This was particularly noticeable with the mode selection in the "loop" position, but existed to an appreciable extent in the other modes as well. The volume control would not turn the volume completely down, and this caused pilot discomfort and inconvenience.

2.2.3.7. Helicopter Sling Loads. No adverse effects were noted when the helicopter was carrying external sling loads.

2.2.3.8. Fail-Safe Function. A fail-safe device was not installed in any of the systems tested.

2.2.3.9. Pilots' Evaluation. As part of the post-flight comments required upon completion of each test flight, the pilots were asked to rate subjectively the overall performance in flight of the system, in comparison with the AN/ARN-59, as: "Better Than," "As Good As," or "Worse Than." A summary of these ratings follows:

	No. of Ratings.	"Better Than"	"As Good As"	"Worse Than
Aqua	14	6	8	-
Maroon	9	-	1	8
Salmon	9	7	2	-

2.2.4. Analysis.

2.2.4.1. Salmon had an average maximum usable range one-third greater than either of the other two systems.

2.2.4.2. Salmon was not as noisy in the "loop" position as either of the other systems.

2.2.4.3. Maroon was adversely affected by thunderstorm activity to such an extent that it was not usable.

2.2.4.4. Overall performance in flight of Salmon was appreciably better than that of the other systems.

2.3. TECHNICAL SUITABILITY.

Tests to determine technical suitability were conducted at USAEPG. Results are shown in USAEPG's final report (part A of section 3).

2.4. MAINTENANCE AND SUPPORT REQUIREMENTS.

2.4.1. Objective.

To determine the maintenance and support requirements for the ADF systems.

2.4.2. Method.

2.4.2.1. The total operating time of the installed test systems and the bench test system was recorded. All failures, causes of failures, time required for repairs, and the parts required for repair were recorded so far as practical. All failures, airborne and bench test for all test systems, were compared.

2.4.2.2. The test systems were evaluated to determine the ease of maintenance of the components to include examination of packaging, density of components, difficulty of location of failure and component change, and availability and accessibility of test points.

2.4.2.3. Maintenance required on the test systems was performed utilizing the standard avionic maintenance tool kits and any additional tools required were noted.

2.4.2.4. Standard avionic test equipment was utilized for checking the test equipment and the requirement for special test instruments necessary for maintenance of the test system was determined.

2.4.2.5. The major components of the test systems were evaluated to determine the requirement for nonstandard parts, high cost items,

or critical parts for replacement, and the availability of these parts in Army supply channels.

2.4.2.6. The test systems were evaluated to determine the scope of avionic maintenance and skill level (MOS) required for performance.

2.4.2.7. The test systems were evaluated to determine the design adequacy of connectors and plugs to provide a safe go-no-go connection. Self-test features (if present) were evaluated for adequacy, readability, and desirability.

2.4.2.8. Records were maintained to reflect the time and number of personnel required to identify malfunctions and the time and number of personnel required to perform inspections. The interval of inspection and alignment was determined so far as practical.

2.4.3. Results.

2.4.3.1. Total operating time of the airborne and the bench test systems, cause of failures, and parts required for repair were as follows:

System	Operating Hours	Cause of Failures	Parts Required for Repair
Aqua	281.5	Failure of transistor (Q903) and diode (CR903) in ADF amplifier	Transistor (Q903); diode (CR903)
		Loose connection in the goniometer RF input wiring	None
Maroon	230.7	Audio output setting out of adjustment	None
Salmon	293.9	Failure of transistor (Q17) in receiver	Transistor (Q17)
		High-resistance short in wafer switch (S-302A) in control panel	None

2.4.3.2. All sets were easily maintained. Packaging density presented no problems; failures were readily located, and components were easily changed. Test points were adequate and accessible.

2.4.3.3. TK-87/U tool set and TK-88/U tool set were adequate for organizational and field maintenance respectively. No additional tools were required.

2.4.3.4. Standard signal generators and meters were adequate. Bench test set for the AN/ARN-59 was not compatible or adaptable to the new systems. Special test panels were determined to be necessary for equipment testing and calibration.

2.4.3.5. Generally, standard parts were used in all sets. Some parts were not readily identifiable because Federal Stock Numbers cross reference information was not available.

2.4.3.6. An Aviation Electronic Equipment Mechanic (MOS 284.1) could perform organizational maintenance without additional training. An Aviation Electronic Equipment Repairman (MOS 284.2) could perform field maintenance after 24 hours of formal training and 16 hours of on-the-job training.

2.4.3.7. The design of connectors and plugs provided a safe go-no-go connection. No system had a self-test feature.

2.4.3.8. Malfunctions and maintenance time are presented in appendix I.

2.4.3.9. Identification of malunctions presented no problem on any of the systems.

2.4.3.10. Existing periodic maintenance inspection intervals for airborne electronic equipment applied to each of the test items. Insufficient maintenance data were collected to warrant any change in the existing inspection intervals.

2.4.4. Analysis.

2.4.4.1. None of the systems presented any maintenance or support difficulties.

2.4.4.2. All of the systems developed discrepancies prior to 30 hours of flight testing.

2.4.4.3. Because of the limited time allotted for this evaluation, the degree of reliability could not be accurately determined for each system. The discrepancies and failures which occurred were not considered to be indicative of low reliability.

2.5. DEFICIENCIES.

2.5.1. Objective.

To determine the existence of any deficiency* which would preclude Army acceptance of the ADF Systems.

2.5.2. Method.

The results of tests outlined above were analyzed in detail to determine whether disqualifying deficiencies exist in the test systems.

2.5.3. Results.

Aqua and Salmon each had four deficiencies and Maroon had eight deficiencies. A detailed list of deficiencies and shortcomings together with suggested corrective action is contained in appendix II, section 4.

2.5.4. Analysis.

Not applicable.

*A defect which serves as a bar to type classification. See appendix II, section 3, for the detailed definition quoted from USATECOM Regulation 705-7.

SECTION 3

REPORTS FROM OTHER TEST AGENCIES

PART A - USAEPG REPORT

PART B - USAHEL REPORT

PART A

USAEPG REPORT

MILITARY POTENTIAL TEST

OF

AUTOMATIC DIRECTION FINDING EQUIPMENT

U. S. ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZONA

FINAL REPORT
OF
MILITARY POTENTIAL TEST
(COMPARATIVE EVALUATION)
AUTOMATIC DIRECTION FINDING EQUIPMENT

DA PROJECT 1-G-6-50212-D-326-08

USATECOM PROJECT 4-4-4316-02

USAEPG PUBLICATION ETA-FR-174

FOR THE COMMANDER:

G. D. ELLERSON
Colonel, Artillery
Deputy Commander

SECTION 1. GENERAL

1.1 REFERENCES

See appendix I.

1.2 AUTHORITY

1.2.1 Directive

Letter, AMSTE-BG, U. S. Army Test and Evaluation Command, 17 March 1964, subject: "Test Directive, USATECOM Project No. 4-4-4316( ), Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment" (appendix II).

1.2.2 Supplement Directive

Letter, AMSTE-BG, U. S. Army Test and Evaluation Command, 22 May 1964, subject: "Supplement Test Directive, USATECOM Project No. 4-4-4316( ), Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment" (appendix II).

1.3 TEST OBJECTIVES

1.3.1 Purpose

The purpose of this Category II test was to obtain data to be used as an input to the overall Military Potential Test (Comparative Evaluation). This overall test will be the basis for selecting suitable automatic direction finding system or systems for Army air navigation.

1.3.2 Objective

To conduct bench tests to determine physical and operational characteristics, technical suitability, and deficiencies of selected commercially-designed ADF equipment. SCL 8012B, as amended, and FAA Technical Standard Order (TSO) C41b were used as criteria.

1.4 RESPONSIBILITIES

1.4.1 U. S. Army Aviation Test Board (USAAVNTBD), Fort Rucker, Alabama, Coordinating Test Agency (CTA) was responsible for reviewing specifications and available data to determine the tests required to evaluate the receivers, conducting tests required to establish the degree to which each receiver meets Army requirements, and preparing and publishing the plan of test and test report.

1.4.2 U. S. Army Electronic Proving Ground (USAEPG), Fort Huachuca, Arizona, Participating Test Agency (PTA) was responsible for conducting bench tests at Fort Huachuca, Arizona, and for furnishing input data to USAAVNTBD.

1.4.3 U. S. Army Aviation Test Activity (USAATA), Edwards Air Force Base, California, PTA, was responsible for reviewing specifications and available data to determine what flight tests will be needed, conducting tests required to establish performance and qualification for airworthiness, and assisting as necessary in the preparation of plan of test and test report.

1.5 DESCRIPTION OF MATERIEL

The test items are lightweight, aircraft compass systems designed to provide automatically a visual indication of the direction from which an incoming radio frequency signal is being received and simultaneous aural reception in the frequency range of 190 to 1750 kilocycles. For purposes of this report, the test items from three manufacturers are identified (Salmon, Aqua, and Maroon) and consist of receiver, control unit or tuner, azimuth indicator, antennas, mountings, necessary cabling, and accessories.

1.6 BACKGROUND

For the past seven years the Automatic Direction Finding Set, AN/ARN-59, has been procured from one company. To insure that equipment contains current state-of-the-art design features, the Assistant Secretary of the Army, on 13 November 1963, directed that future procurement be made by competitive selection.

Before this action could be implemented, however, it was decided in a meeting at USAMC Headquarters, 5 June 1964, to procure replacement items without comparative testing. This was planned so that the required equipment could be procured in sufficient time to meet the FY-66 "dock time" of the procured aircraft. It was also decided to use the minimum technical requirements of the current sets as criteria. Obviously, these procedures would not assure the Army of better equipment since the final selection would be based on "paper" evaluation and price. A few Army personnel outside AMC Headquarters agreed that this would retard Army aviation several years.

A message (USAAVNTBD, STEBG-PR 6-61) dated 19 June 1964 to AMC proposed that AMC perform limited testing on the Automatic Direction Finding sets within a 6-week period, to include engineering tests. However, at the Fort Monmouth meeting held 1 July 1964, it was determined that USAAVNTBD would retain executive responsibility; Fort Rucker would perform the service tests, and USAEPG would conduct bench tests at Fort Huachuca (using duplicate equipment to decrease time and money).

Representatives of AMC, at a meeting in Fort Rucker 17 November 1964, elected that the AN/ARN-59 would not be used in the military potential tests for comparative evaluation.

1.7 FINDINGS

1.7.1 None of the sets met all of the SCL and TSO requirements. Following is a summary showing the compliance of the test items with the requirements (see appendix III for detailed findings):

TEST	SALMON SCL	SALMON TSO	AQUA SCL	AQUA TSO	MAROON SCL	MAROON TSO
Design Features	No	Yes	No	Yes	No	Yes
Physical Characteristics	No	Yes	Yes	Yes	Yes	Yes
AGC Constants	Yes	N/A	Yes	N/A	Yes	N/A
Operational Stability	Yes	N/A	Yes	N/A	Yes	N/A
Calibration Accuracy	Yes	N/A	Yes	N/A	Yes	N/A
Power Consumption	No	Yes	Yes	Yes	Yes	Yes
Receiver Sensitivity	No	Yes	No	Yes	No	Yes
CW Sensitivity	No	Yes	Yes	Yes	Yes	Yes
Noise Level	Yes	Yes	No	Yes	No	Yes
Image Rejection	No	No	Yes	Yes	Yes	No
Receiver Selectivity	No	No	Yes	No	No	No
Loop Sensitivity	No	No	No	Yes	No	No
Compass Sensitivity	No	Yes	No	Yes	No	Yes
Operating Life	N/A	N/A	N/A	N/A	N/A	N/A

Remarks: On Salmon one 28-volt lead-in was improperly insulated. Fast warmup was observed on all sets.

1.7.2 There were no equipment deficiencies and only one shortcoming observed during the testing:

The Salmon loop antenna did not function properly in the highest frequency range. With the set in ADF mode the indicator was subject to "sticking" at approximately 240 degrees. The loop antenna was considered defective, and a replacement was obtained from the manufacturer. The replacement antenna functioned normally.

1.7.3 Technical requirements were inadequate in some of the following areas:

a. There were no criteria for safety or allowable warm-up time.

b. In some cases criteria were spelled out for things which are not necessary or feasible for the equipment, such as a fail-proof device.

c. Criteria were given specifying output loads and output powers which were based on the characteristics of the AN/ARN-59, but which should not have been applied to this test.

1.8 CONCLUSIONS

Based on the findings it is concluded that:

a. No one of the three test items can be endorsed; neither can one item be selected above the others on the basis of the inadequate criteria provided and the limited bench testing done.

b. SCL 8012B was not a satisfactory standard for evaluating these sets.

1.9 RECOMMENDATIONS

It is recommended that:

a. Complete engineering tests be made before any of the test items can be considered for military use.

b. The technical requirements be rewritten to provide clear, realistic specifications in keeping with the latest developments in navigation equipment.

SECTION 2. DETAILS AND RESULTS OF SUBTESTS

2.0 INTRODUCTION

Tests described in this section were performed on each ADF equipment under laboratory conditions as identical as possible. Avionics maintenance was provided by military personnel. Contractor personnel provided initial technical support, monitored any maintenance performed, and certified its validity.

Because of the competitive nature of this comparative evaluation, every effort was made by USAEPG personnel to insure fair and equal treatment to each contractor.

The respective manufacturers of Test Items Salmon, Aqua, and Maroon, provided necessary wiring, connections, and mounts for installation of the test item submitted for test. All operational or user tests were conducted by USAAVNTBD and all bench tests by USAEPG.

2.1 SAFETY

2.1.1 Objective

To define any hazards or potential hazards which may exist in and around the test items and the control methods used to eliminate or minimize these hazards.

2.1.2 Criteria

The equipment shall be safe to install, maintain, and operate through the use of positive control measures, prominently displayed warning notices, or both.

2.1.3 Method

Initial inspection of each test item upon its arrival at USAEPG included an inspection for protrusions, rough surfaces, and possible hazards. The equipment was set up and tested in a laboratory. Proper power was applied to each test item, and a vacuum tube voltmeter (VTVM) was used to test for exposed voltages in excess of 25 volts. A record was made of any hazards incurred by personnel installing, operating, or maintaining the equipment. Notes were also made on potential hazards observed. Presence, position, and adequacy of posted warnings, safety markings, and safety controls were noted.

2.1.4 Results

Item Salmon showed an exposed voltage of 28 volts dc on the power supply located on the rear of the receiver shockmount. Otherwise there were no safety hazards encountered during the bench tests of the receiver sets.

2.1.5 Analysis

There are no comments in the technical requirements regarding safety features. However, all sets appeared to be safe for installation, maintenance, and operation in military aircraft, with very little alteration of the equipment.

2.2 WARMUP TIME

2.2.1 Objective

To determine the average time required for each test item to become fully operational from a POWER-OFF condition.

2.2.2 Criterion

The test item shall be capable of stable operation after a minimum warmup time.

2.2.3 Method

Each test item was in a POWER-OFF condition at least 12 hours before each warmup test. A 25-microvolt signal was applied to the input of the receiver. An automatic time counter was turned on the instant the equipment was turned on. When the receiver output was stabilized, the counter was turned off and the elapsed time recorded. This test was repeated three times for each test item.

2.2.4 Results

The average warmup time was 2.4 seconds for Salmon, 3.9 seconds for Aqua, and 2.5 seconds for Maroon.

2.2.5 Analysis

All of the sets operated normally after a very short warmup interval.

2.3 DESIGN FEATURES

2.3.1 Objective

To determine whether each test item contains the design features specified in applicable portions of the SCL 8012B.

2.3.2 Method

Each test item was checked against the design features listed in Table I. Any other features of importance were noted.

2.3.3 Results

See Table I.

2.3.4 Analysis

All of the sets met the technical requirements with the following alternates or exceptions: None of the sets had an alternate bearing circuit, but all of them had an acceptable goniometer circuit as permitted in the technical requirements. Fail-safe devices were not provided but were not required by TSO C41b.

TABLE I. DESIGN FEATURES

Design Feature	Test Item		
	Salmon	Aqua	Maroon
Primary Supply, Solid State Devices	Yes	Yes	Yes
Sense Antenna	Yes	Yes	Yes
Loop Antenna	Yes	Yes	Yes
Beat Frequency Oscillator	Yes	Yes	Yes
Bearing Indicator	Yes	Yes	Yes
Alternate Bearing Circuit	No	No	No
Automatic Loop	Yes	Yes	Yes
Audio Output	Yes	Yes	Yes
Loop L-R Control	Yes	Yes	Yes
Tuning Indicator	Yes	Yes	Yes
Edge Lighting	Yes	Yes	Yes
Fail-Safe Device	No	No	No
Frequency Range (190 to 1,750 kc)	Yes	Yes	Yes

2.4 PHYSICAL CHARACTERISTICS

2.4.1 Objective

To determine weight, dimensions, and other physical characteristics of each test item.

2.4.2 Criteria

The equipment shall be of a size and weight suitable for installation in the cockpit of any Army aircraft. The weight of one completely assembled, operative equipment (less cables) shall not exceed 20 pounds. The volume of the equipment less cables shall not exceed 750 cubic inches.

2.4.3 Method

The test items were measured and weighed. Overall dimensions including protrusions were considered. The height, width, depth, volume, and weight were recorded.

2.4.4 Results

The results are shown in Table II.

2.4.5 Analysis

All of the sets met the technical criteria with regard to weight, but Salmon did not meet the requirements with regard to volume. It will be noted that the volume requirement was based on the volume of the AN/ARN-59. However, this measurement did not include the knobs and cable connectors in the depth measurements; that is, the measured volume was not the total useful volume occupied by the equipment. There is no volume restriction in the TSO C41b.

TABLE II. PHYSICAL CHARACTERISTICS

Test Item	Height (in.)	Width (in.)	Depth (in.)	Volume (cu in.)	Weight (lb)	Weight (oz)
Salmon						
Receiver in Shockmount	9 1/16	3-5/16	16	480.3	10	13
Control Unit or Tuner	2-5/8	5-3/4	4-15/16	74.5	1	12
Loop Antenna	7/8	12	16	168.0	4	8
Bearing Indicator	3-1/4	3-1/4	4-3/16	44.2	1	3
Total				767.0	18	4
Aqua						
Receiver in Shockmount	4-1/2	2-9/16	16-1/2	192.6	4	13
Control Unit or Tuner	3-3/4	5-3/4	7-1/4	156.3	4	4
Loop Antenna	15/16	9-7/8	16-7/8	153.4	3	7
Bearing Indicator	3-1/4	3-1/4	5-11/16	60.2	1	15
Total				562.5	14	7
Maroon						
Receiver in Shockmount	7-9/16	3-1/4	15	368.6	6	11
Control Unit or Tuner	3-3/4	5-3/4	7-1/2	161.7	7	7
Loop Antenna	2	6-3/8	6-3/8	81.3	3	7
Bearing Indicator	3-1/4	3-1/4	4-3/16	44.2	1	4
Total				655.9	18	13

2.5 AGC CONSTANTS

2.5.1 Objective

To ascertain that the delay time of the AGC circuit between "signal" and "no signal" interval is appropriate.

2.5.2 Criteria

The AGC constants shall be chosen to allow for taking a bearing on a modulated or CW signal whose carrier is interrupted by a keying sequence of 3 dots per second, each dot lasting a maximum of 1/6 of a second.

2.5.3 Method

2.5.3.1 The input signal was interrupted as specified in the criteria stated in paragraph 2.5.2 above.

2.5.3.2 With the receiver in ADF mode the bearing response was observed. A notation was made as to whether the direction finder was able to take a bearing under these conditions.

2.5.4 Results

All of the sets were able to respond appropriately in spite of the signal interruption. In each case the indicators followed the signal interruption by fluctuating between the true bearing and a few degrees off true bearing, corresponding to signal 'ON' and signal 'OFF' respectively.

2.5.5 Analysis

All of the sets met the technical requirements.

2.6 OPERATIONAL STABILITY

2.6.1 Objective

To determine the operational stability of each test item.

2.6.2 Criterion

There shall be no evidence of overloading, blocking, or unstable operation in any circuit when the RF voltage is as high as 0.1 volts at the sense antenna input.

2.6.3 Method

2.6.3.1 A distortion analyzer and a dual beam oscilloscope were used for this test. A 1000-cps, 30-percent tone-modulated signal was applied to the input terminal of the receiver. Intensity of the input signal was varied from 1000 microvolts to 0.1 volt, or until distortion occurred. The gain control was adjusted for a 20-milliwatt output for each setting of input signal.

2.6.3.2 Input and output signals were observed on the scope, and percent of distortion was recorded. Also, any instability present during the test was noted.

2.6.4 Results

The results of this test are shown in Table III.

2.6.5 Analysis

All of the receiver sets met the technical requirements pertaining to overloading, blocking, or instability with an input signal as high as 0.1 volts. The difference in distortion percentage between sets is due to the different operating output for each set and reflects mainly the difference in gain setting necessary for a 20-milliwatt output.

TABLE III. OUTPUT AND DISTORTION

Salmon			Aqua			Maroon		
Input (Volts)	Output (Volts)	Distortion (%)	Input (Volts)	Output (Volts)	Distortion (%)	Input (Volts)	Output (Volts)	Distortion (%)
0.001	4.5	1.90	0.001	4.3	1.20	0.001	3.0	7.90
0.003	4.6	1.90	0.003	4.1	0.72	0.003	3.0	7.90
0.010	4.5	1.85	0.010	4.0	0.66	0.010	2.9	7.90
0.030	4.7	1.85	0.030	4.0	0.66	0.030	3.0	7.85
0.10	4.7	1.80	0.10	4.0	0.66	0.10	3.0	7.85
0.30	4.6	1.85	0.30	4.2	0.66	0.30	3.0	7.90
3.0	4.2	4.1C	3.0	4.0	3.20	3.0	3.3	26.8

2.7 CALIBRATION ACCURACY

2.7.1 Objective

To determine the calibration accuracy and backlash of the tuning mechanism.

2.7.2 Criteria

The calibration accuracy and the backlash in the tuning mechanism shall be such that the maximum error in setting the dial does not exceed 0.5 percent of the frequency desired. For any combination of service conditions, the calibration error shall not exceed 1.0 percent of any desired frequency.

2.7.3 Method

A calibrated signal generator was used to apply the input signal. The test item was turned to an easily-read frequency setting, and the input signal frequency was varied until maximum signal output was obtained. The frequency setting of the tuning mechanism was recorded. Also recorded was the frequency at which the signal generator permitted maximum signal output.

2.7.4 Results

The results are shown on Table IV.

2.7.5 Analysis

All of the sets met the technical requirements.

TABLE IV. CALIBRATION ACCURACY OF TUNING MECHANISM

Salmon			Aqua			Maroon		
Input Freq (KC)	Rec Setting (KC)	Error (%)	Input Freq (KC)	Rec Setting (KC)	Error (%)	Input Freq (KC)	Rec Setting (KC)	Error (%)
210.67	210	0.32	209.76	210	0.11	208.88	210	0.53
452.25	450	0.50	449.75	450	0.06	449.09	450	0.20
954.84	950	0.51	950.27	950	0.03	949.00	950	0.11

2.8 POWER CONSUMPTION

2.8.1 Objective

To determine the power requirements of each test item.

2.8.2 Criteria

Except for the initial operating transient, and during operation of the "LOOP LEFT-RIGHT" control switch, the direct current required to operate the equipment shall not be greater than 1.0 ampere at 26.5 volts. Operation of the loop control switch shall not increase the current more than 0.25 amperes.

2.8.3 Method

Testing was conducted according to conditions established in the criteria above. The equipment was operated with the input voltage adjusted to 26.5 volts dc. During normal operation and during "LOOP LEFT-RIGHT" operation, the respective currents were recorded.

2.8.4 Results

Input voltage for all modes of operation was 26.5 volts dc. Current in amperes for all modes of operation did not exceed the following:

	SALMON	AQUA	MAROON
ADF, Loop or Antenna	1.05	0.69	0.68
Loop Left-Right	1.05	0.89	0.70

2.8.5 Analysis

Items Aqua and Maroon met the technical requirements, but Salmon did not. The TSO does not have any requirements for power consumption.

2.9 RECEIVER SENSITIVITY

2.9.1 Objective

To determine the capability of the receiver to respond to weak input signals.

2.9.2 Criteria

The sensitivity of the receiver throughout its frequency range shall be such that an input signal of 5 microvolts modulated 30 percent by 1000 cps will produce a 6-db signal-plus-noise-to-noise ratio at the audio output.

2.9.3 Method

Tests were conducted according to criteria established above. The input signal and the audio gain were adjusted so that the output power across a matched load was approximately 20 percent of the rated output with a 6-db signal-plus-noise-to-noise ratio.

2.9.4 Results

The results of this test are shown in Table V.

2.9.5 Analysis

None of the sets satisfied the criteria established in paragraph 2.9.2 above. However, they all easily met the requirements of the TSO C 41b, which calls for a sensitivity not in excess of 70 microvolts/meter under conditions nearly the same as were actually present. It is noted here that the specifications for this test in the technical requirements appear unrealistic in that they take no account of the variations in output impedance and design power output of different receivers.

TABLE V. RECEIVER SENSITIVITY

Item	Receiver Frequency (KC)	Input Signal (Microvolts)	Output Power MCW (Milliwatts)	Output Power CW (Milliwatts)
Salmon	400	22	20	5.0
	800	12	20	5.0
	1600	13	20	5.0
Aqua	400	17	50	12.5
	800	8	50	12.5
	1600	8	50	12.5
Maroon	400	8	50	12.5
	800	6	50	12.5
	1600	5	50	12.5

2.10 CW SENSITIVITY

2.10.1 Objective

To determine the carrier wave (CW) sensitivity of each test item.

2.10.2 Criterion

The CW sensitivity shall be equal to that specified for a 30-percent, 1000-cps modulated signal.

2.10.3 Method

The tests were conducted and the readings recorded as described in test 2.9 except that the Beat Frequency Oscillator (BFO) was used.

2.10.4 Results

The results of this test are shown in Table VI.

2.10.5 Analysis

Aqua and Maroon met the technical requirements which specified a 50-milliwatt output across a 150-ohm load. Salmon met the sensitivity requirement of 5 microvolts only when a matched load was used with a power output consonant with the design output of the set. This output and resulting sensitivity are shown in the results (Table VI). Salmon was not capable of giving a 50-milliwatt output across a 150-ohm load at most frequencies, but as mentioned in the previous test, such a requirement is unrealistic. All of the sets easily met the requirements of the TSO.

TABLE VI. CW SENSITIVITY

Item	Receiver Frequency (KC)	Input Signal (Microvolts)	Output Power	
			CW+BFO (Milliwatts)	No Signal (Milliwatts)
Salmon	400	3.3	20	5.0
	800	2.8	20	5.0
	1600	2.2	20	4.5
Aqua	400	4.5	50	12.5
	800	2.2	50	12.5
	1600	3.0	50	12.5
Maroon	400	3.6	50	12.5
	800	1.7	50	12.5
	1600	3.3	50	4.0

2.11 RECEIVER NOISE LEVEL

2.11.1 Objective

To determine the level of overall receiver noise.

2.11.2 Criteria

The noise level of this equipment shall not exceed 35 milliwatts for any calibrated frequency within the frequency range with the "AUDIO" control at the maximum gain position. The noise level shall not exceed 25 microwatts at any calibrated frequency with the "AUDIO" control at the minimum gain position.

2.11.3 Method

2.11.3.1 The noise level at receiver output was measured with a power meter.

2.11.3.2 The noise level at minimum gain control position and the noise level at maximum gain position were recorded.

2.11.4 Results

The results of this test are shown in Table VII.

2.11.5 Analysis

2.11.5.1 Maximum Gain. Salmon met the technical requirements. The maximum noise was 30-milliwatts in the frequency range 250 to 300 kc. Aqua did not meet the technical requirements, and Maroon met the technical requirements only from 600 to 1750 kc. It will be noted that Aqua is designed so that the automatic gain control (AGC) voltage is increased as the volume is increased; thus, the high noise level at high gain is not necessarily detrimental to the sensitivity of the receiver. TSO C41b does not impose any restriction on the noise level at maximum gain.

2.11.5.2 Minimum Gain. All of the sets easily met the technical requirements in that the output power was less than 10 microwatts over the entire frequency range.

TABLE VII. POINTS OF MAXIMUM NOISE

(Gain Set at Maximum)

Frequency Range (KC)	Noise Level (Milliwatts)		
	Salmon	Aqua	Maroon
190-250	< 30	1100	180
250-300	30	1000	150
300-350	< 30	1200	> 35
350-400	< 30	1100	> 35
400-500	< 30	1400	170
500-600	14	1400	120
600-700	< 14	1400	7
700-850	10	1400	12
850-1050	5	1450	20
1050-1250	5	1400	20
1250-1450	5	1450	20
1450-1750	5	1400	< 20

2.12 IMAGE REJECTION

2.12.1 Objective

To determine the amount of image rejection in the ADF receiver.

2.12.2 Criteria

The image rejection shall not be less than the following allowable power ratios:

Band	db
Low	80
Mid	80
High	70

2.12.3 Method

A convenient signal tone-modulated 30 percent was applied to the receiver so that a power output of approximately 20 percent of rated output was obtained. The signal input frequency was tuned to the receiver for center frequency testing, followed by image frequency selection on the signal generator. The input signal strength was adjusted so that the original power output was again obtained. The input signals required for center frequency and image frequency were recorded.

2.12.4 Results

The results of this test are shown in Table VIII.

2.12.5 Analysis

Salmon does not meet the technical requirements on the low band but does meet them on the other two bands. Aqua and Maroon both meet the technical requirements. The specifications in TSO C41b call for an 80-db-rejection of any spurious response throughout the frequency range. This is actually a more stringent requirement than called for by SCL 8012B. Only Aqua met this requirement at all frequencies tested.

TABLE VIII. IMAGE REJECTION

Item	Receiver Frequency (KC)	Signal Input Frequency (KC)	Signal Input Level (Millivolts)	Rejection Ratio (Decibels)
Salmon	340	340	0.03	74.8
	340	625	165	
	650	650	0.03	81.3
	650	935	350	
	1400	1400	0.07	69.9
	1400	1685	220	
Aqua	340	340	0.020	88.0
	340	625	500	
	650	650	0.012	100.1
	650	935	1200	
	1400	1400	0.013	92.0
	1400	1685	520	
Maroon	190	190	0.015	92.3
	190	330	620	
	340	340	0.012	92.2
	340	480	490	
	800	800	0.010	100.0
	800	1325	1000	
	1600	1600	0.008	70.9
	1600	2120	28	

2.13 RECEIVER SELECTIVITY

2.13.1 Objective

To determine the receiver selectivity for each test item.

2.13.2 Criteria

The overall bandwidths shall be 4 kc ±1.0 kc at 6 db down and 12 kc ±2.0 kc at 60 db down from the midpoint reference.

2.13.3 Method

A signal modulated 30 percent at 1000 cps was applied to the receiver and adjusted for a convenient output power with a 10 db signal-plus-noise-to-noise ratio. The frequency was changed above and below the center frequency by 1 kc increments, and at each setting the input signal was adjusted to produce the original output power. The frequency variation, input signal strength, and corresponding decibel readings were recorded.

2.13.4 Results

The results of this test are shown in Table IX and in Graphs 1 through 9.

2.13.5 Analysis

2.13.5.1 Salmon met the technical requirements in the two higher frequency bands but was narrower in response than is permissible at the 60 db level for 210 kc. Aqua met the technical requirements at all frequencies tested. Maroon met the technical requirements for the two lower frequencies, but was broader in response than permissible at the 60 db level for 1650 kc.

2.13.5.2 The maximum permissible bandwidths according to TSO C41b are shown on the graphs. It can be seen that none of the sets meet the requirements of the TSO at all frequencies tested.

TABLE IX. RECEIVER SELECTIVITY

Salmon			Aqua			Maroon		
Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels
			204	48	60.5	204	55	67.2
205	210	70.7	205	12	48.5	205	15	55.9
206	12	45.8	206	1.8	32.0	206	1.95	38.2
207	0.69	21.0	207	0.31	16.7	207	0.22	19.2
208	0.13	6.5	208	0.110	7.8	208	0.049	6.2
209	0.084	2.7	209	0.064	3.1	209	0.026	0.76
210	0.062	0	210	0.045	0	210	0.024	0
211	0.090	3.3	211	0.068	3.6	211	0.029	1.6
212	0.16	8.3	212	0.13	9.2	212	0.056	7.3
213	0.89	23.2	213	0.70	23.8	213	0.083	10.8
214	15.7	48.1	214	7.5	44.4	214	0.085	11.0
215	251	72.2	215	65	63.2	215	0.458	25.6
						216	16	56.5
						217	40	64.4

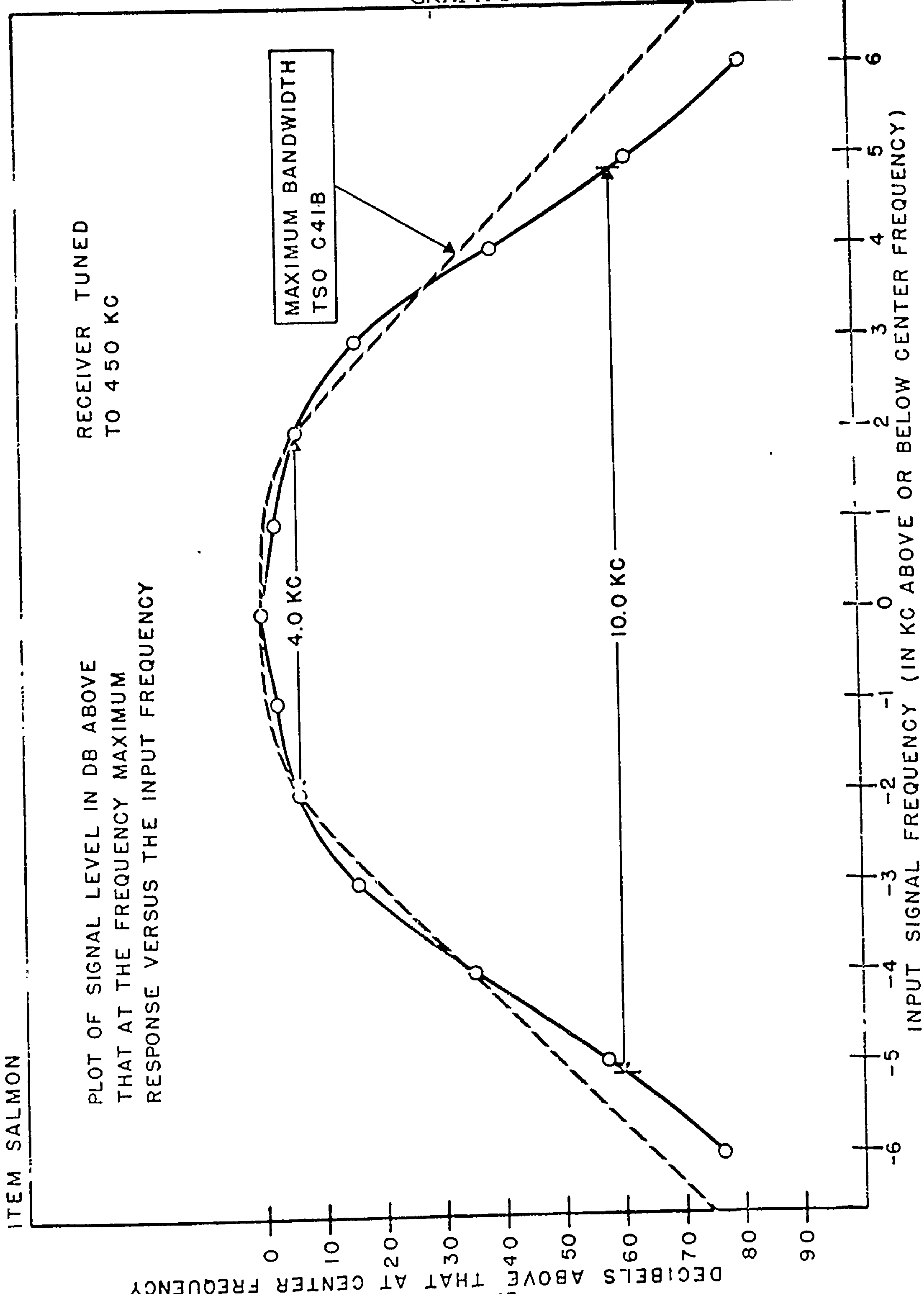
TABLE IX. RECEIVER SELECTIVITY (Continued)

Salmon			Aqua			Maroon		
Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels
			443	250	80.4	443	12	59.3
444	255	76.0	444	15	55.9	444	3.5	48.6
445	30	57.4	445	3.5	43.3	445	0.80	35.8
446	2.4	35.5	446	0.615	28.2	446	0.29	27.0
447	0.124	16.0	447	0.110	13.2	447	0.090	16.8
448	0.082	6.1	448	0.046	5.7	448	0.027	6.2
449	0.055	2.7	449	0.030	1.9	449	0.015	1.2
450	0.041	0	450	0.024	0	450	0.013	0
451	0.055	2.6	451	0.040	4.4	451	0.019	3.3
452	0.080	5.9	452	0.070	9.3	452	0.027	6.3
453	0.275	16.6	453	0.30	21.9	453	0.026	6.1
454	3.9	39.7	454	2.1	38.8	454	0.036	.8.8
455	54	62.5	455	16	56.5	455	0.295	27.1
456	520	82.2	456	96	72.0	456	2.7	46.3
						457	15.8	61.7

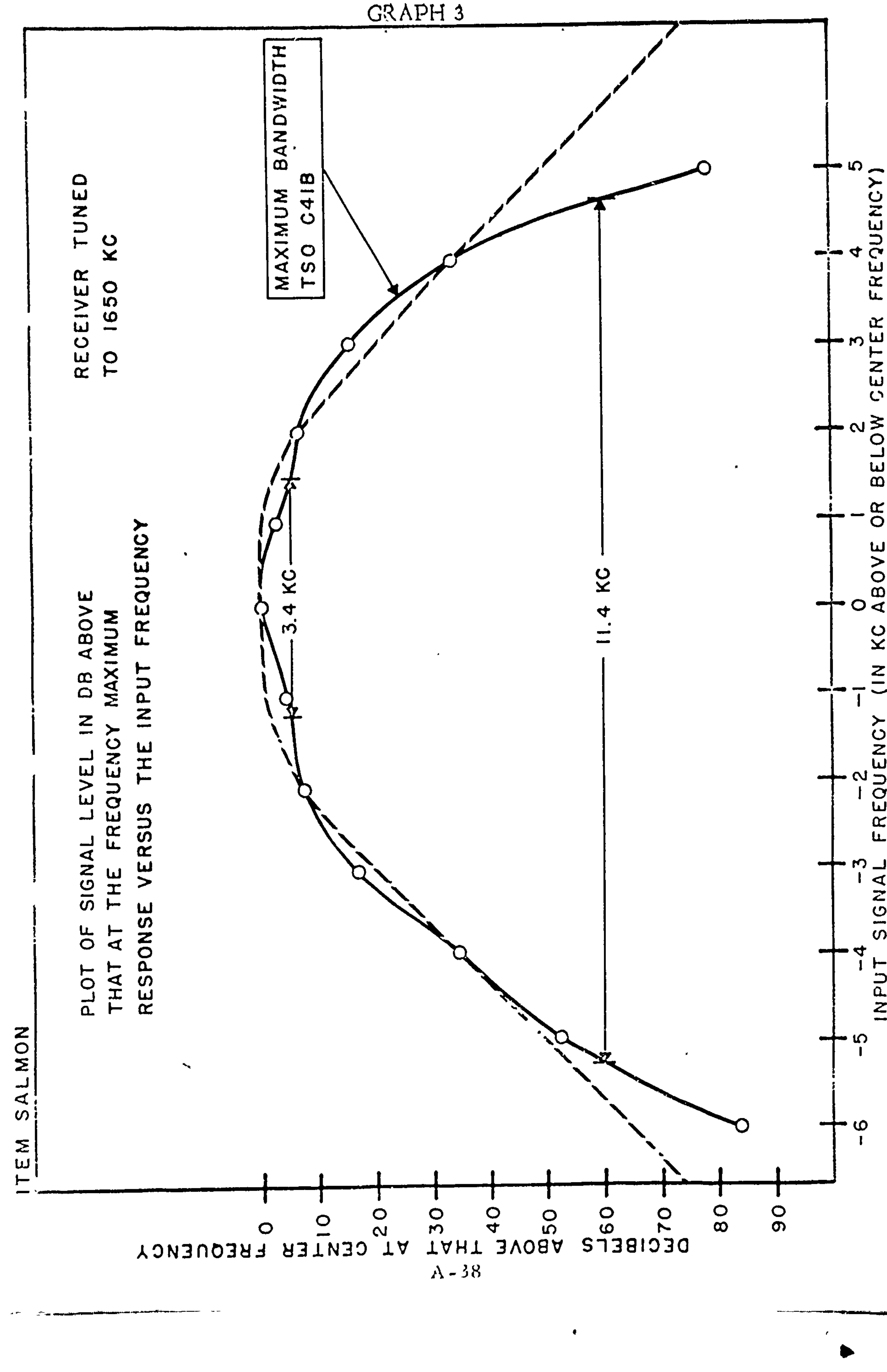
TABLE IX. RECEIVER SELECTIVITY (Continued)

Salmon			Aqua			Maroon		
Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels	Input Freq (KC)	Input Voltage (Millivolts)	Decibels
						1641	26	68.3
						1642	8.0	58.1
			1643	27	68.6	1643	2.4	47.6
1644	290	84.0	1644	7.6	57.6	1644	0.76	37.6
1645	8.0	52.9	1645	1.6	44.1	1645	0.17	24.6
1646	1.0	34.8	1646	0.275	28.8	1646	0.046	13.3
1647	0.040	16.7	1647	0.050	14.0	1647	0.022	6.6
1648	0.037	6.2	1648	0.0155	3.8	1648	0.016	4.1
1649	0.029	4.0	1649	0.0125	1.9	1649	0.012	1.6
1650	0.018	0	1650	0.010	0	1650	0.010	0
1651	0.024	2.4	1651	0.0125	1.9	1651	0.014	2.9
1652	0.036	5.9	1652	0.020	6.0	1652	0.024	7.6
1653	0.100	14.8	1653	0.060	15.6	1653	0.21	26.4
1654	0.90	33.9	1654	0.32	30.1	1654	0.90	39.1
1655	180	79.9	1655	2.7	48.6	1655	2.7	48.6
			1656	14	62.9	1656	9.5	59.6

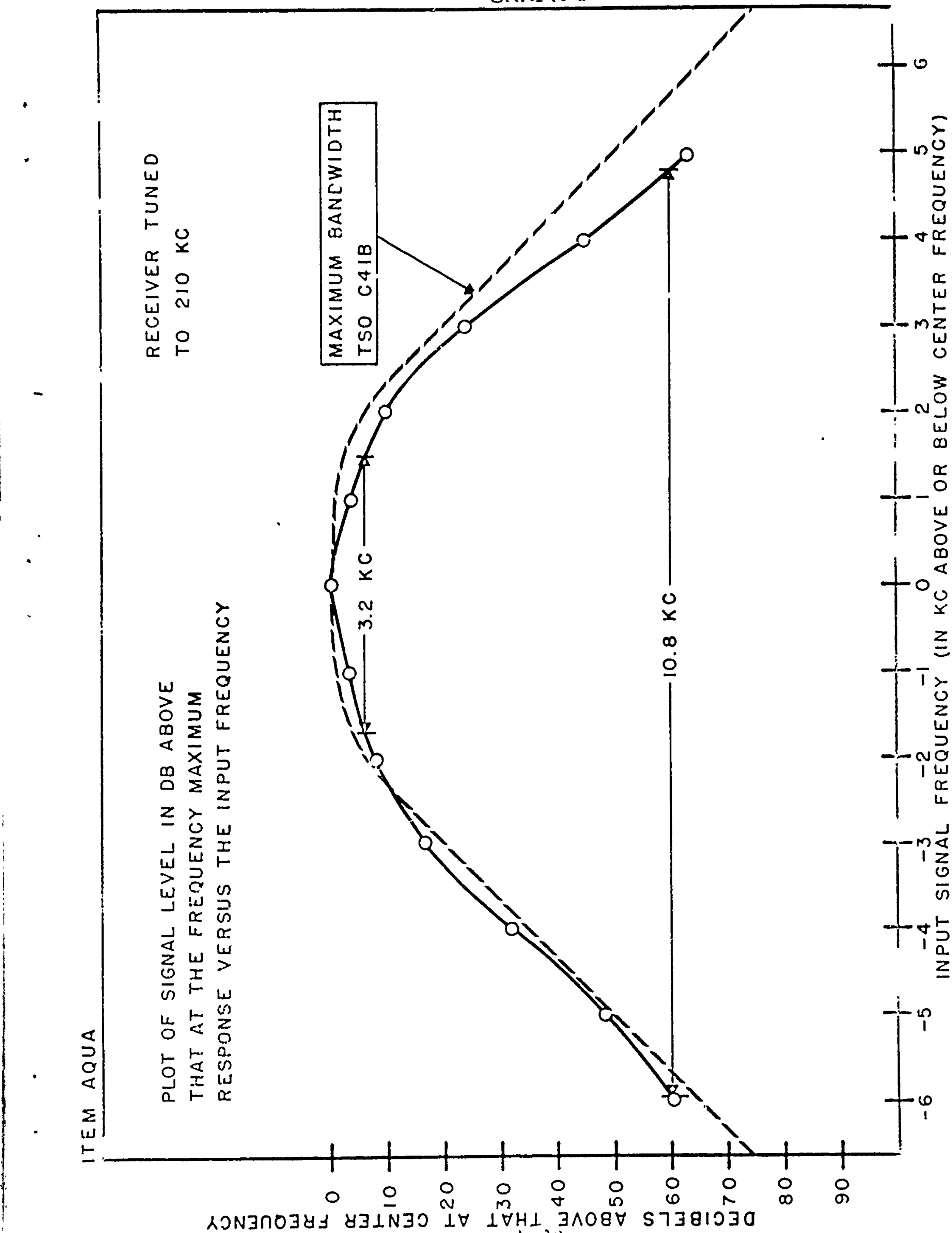
GRAPH 2


ITEM SALMON
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED
TO 450 KC
MAXIMUM BANDWIDTH
TSO C41B
4.0 KC
10.0 KC
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
DECIBELS ABOVE THAT AT CENTER FREQUENCY
0
10
20
30
40
50
60
70
80
90

GRAPH 3

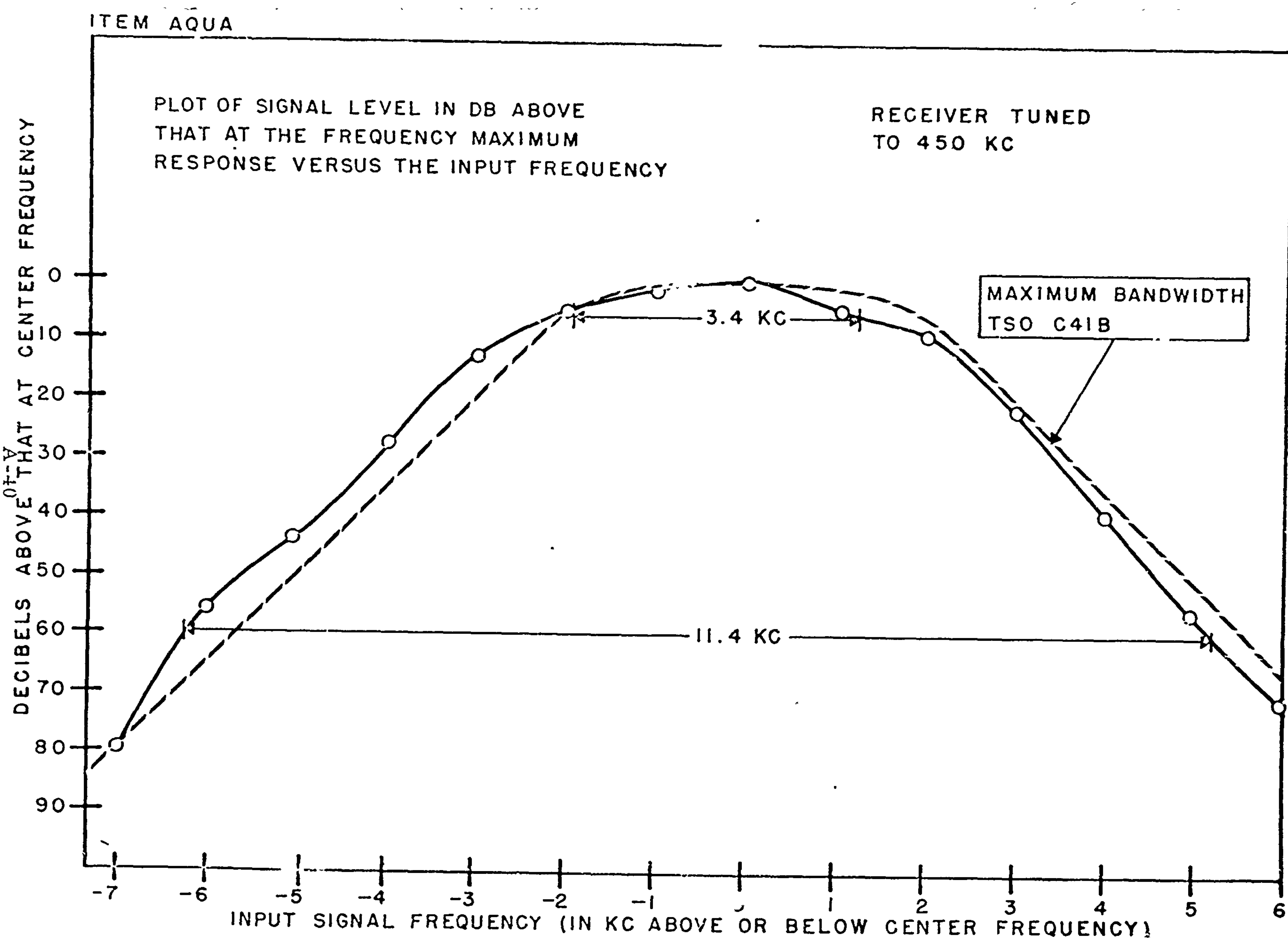

ITEM SALMON
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED
TO 1650 KC
MAXIMUM BANDWIDTH
TSO C41B
3.4 KC
11.4 KC
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)
0
10
20
30
40
50
60
70
80
90
DECIBELS ABOVE THAT AT CENTER FREQUENCY

GRAPH 4

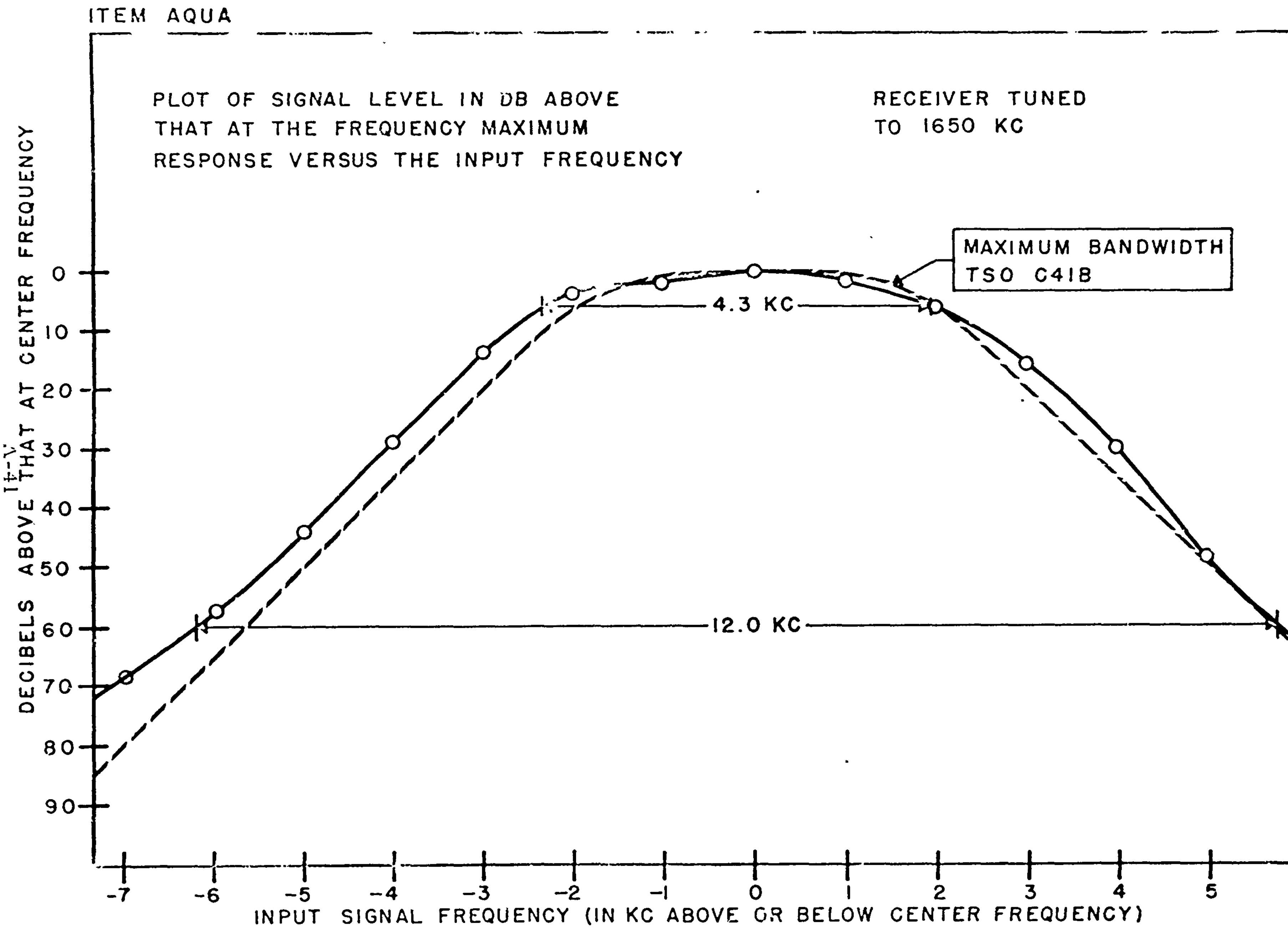


ITEM AQUA
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED
TO 210 KC
MAXIMUM BANDWIDTH
TSO C41B
3.2 KC
10.8 KC
DECIBELS ABOVE THAT AT CENTER FREQUENCY
0
10
20
30
40
50
60
70
80
90
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6

GRAPH 5


ITEM AQUA
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED
TO 450 KC
MAXIMUM BANDWIDTH
TSO C41B
3.4 KC
11.4 KC
DECIBELS ABOVE THAT AT CENTER FREQUENCY
0
10
20
30
40
50
60
70
80
90
-7
-6
-5
-4
-3
-2
-1
1
2
3
4
5
6
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)

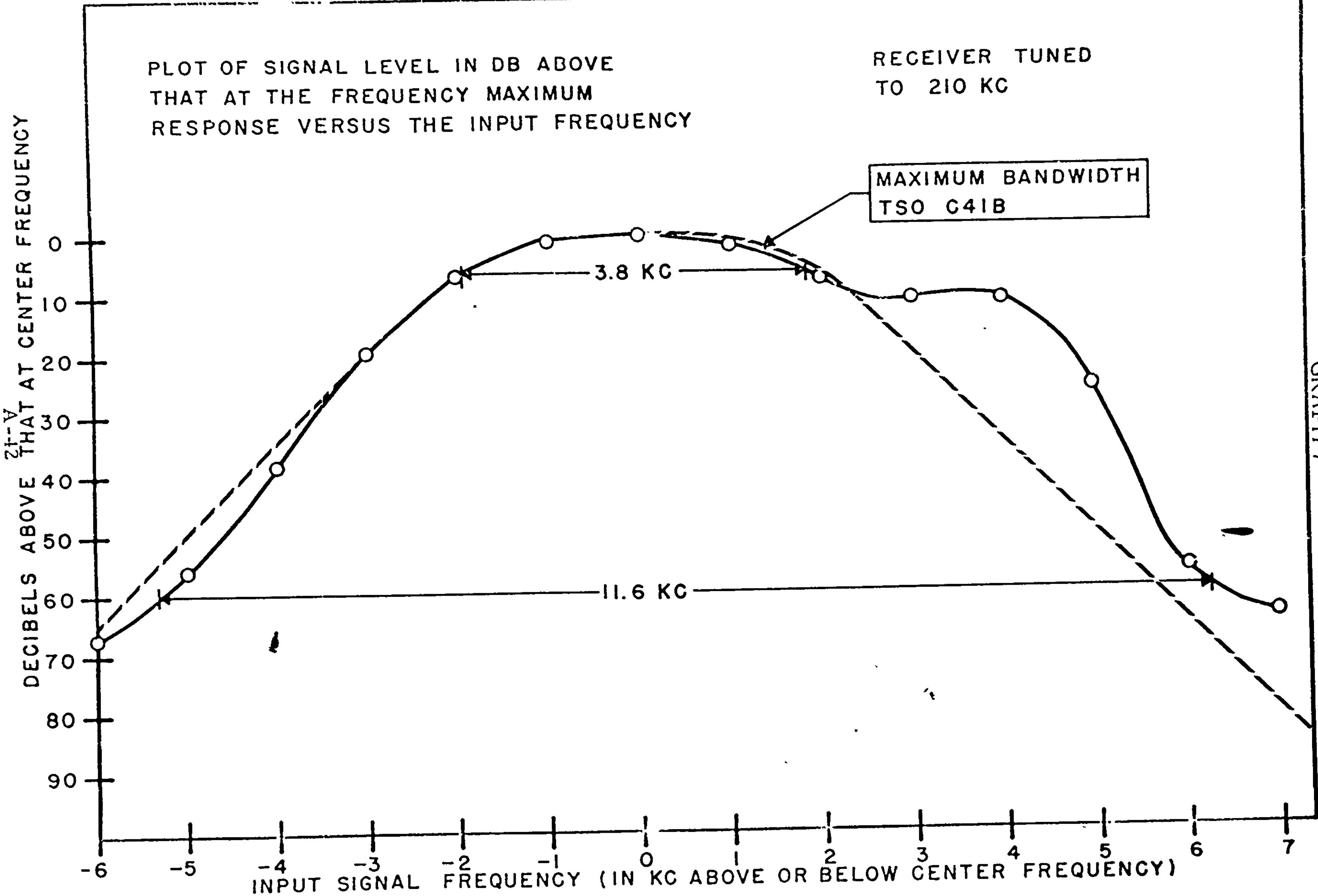
GRAPH 6



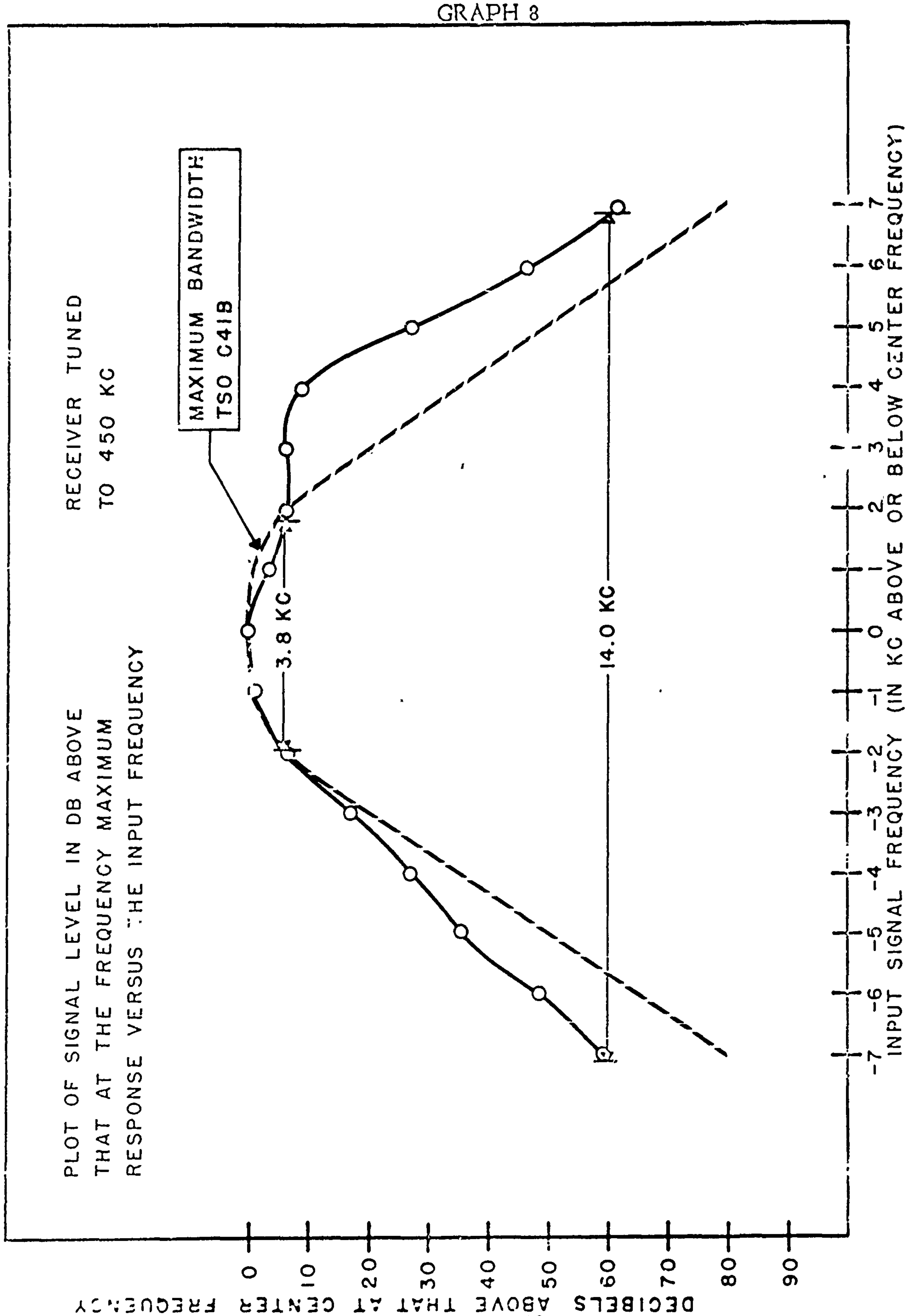
ITEM AQUA
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED
TO 1650 KC
MAXIMUM BANDWIDTH
TSO C41B
4.3 KC
12.0 KC
0
10
20
30
40
50
60
70
80
90
DECIBELS ABOVE THAT AT CENTER FREQUENCY
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)

GRAPH 7

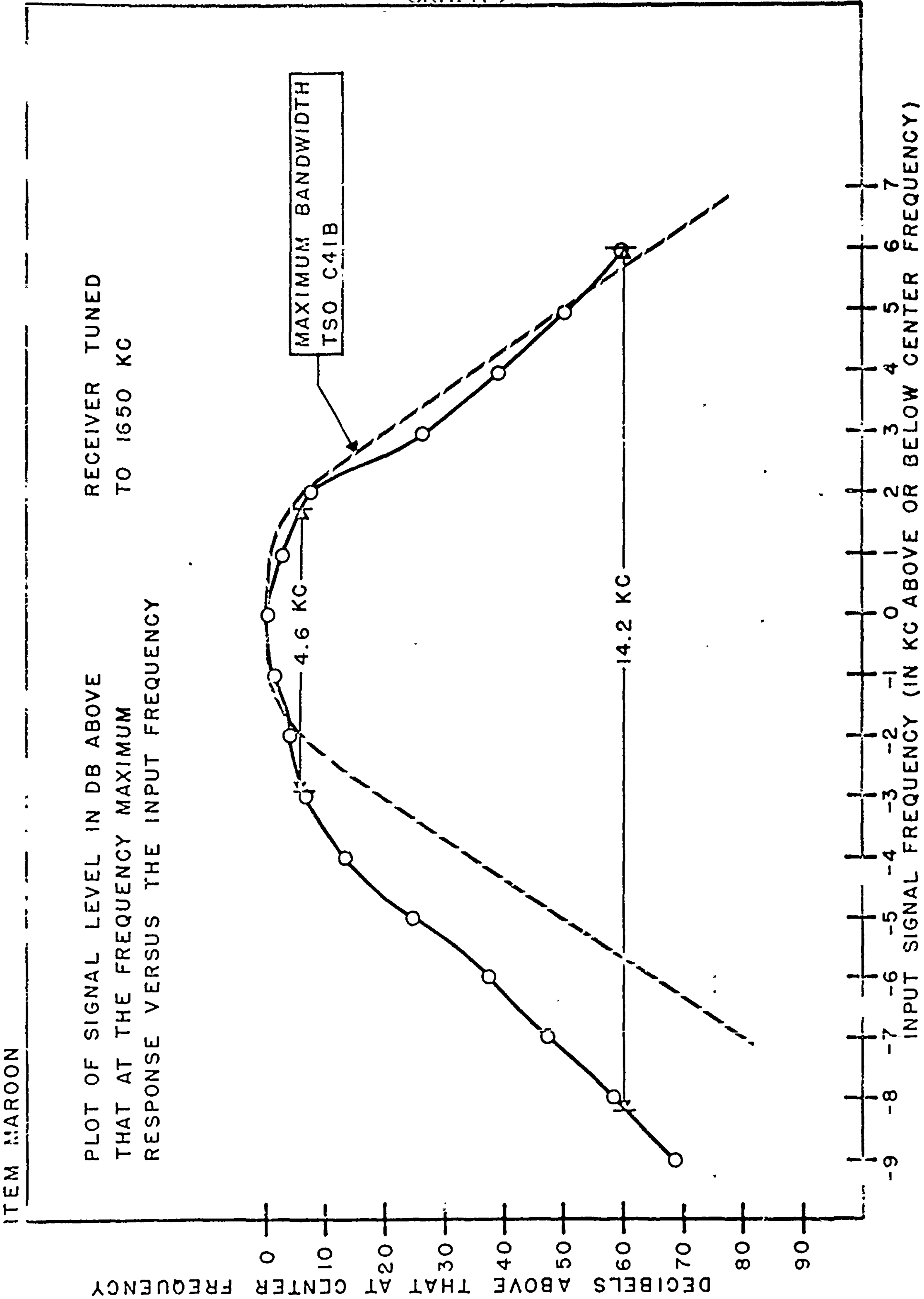
ITEM MAROON



GRAPH 8


RECEIVER TUNED
TO 450 KC
MAXIMUM BANDWIDTH
TSO C41B
PLOT OF SIGNAL LEVEL IN DB ABOVE
THAT AT THE FREQUENCY MAXIMUM
RESPONSE VERSUS THE INPUT FREQUENCY
3.8 KC
14.0 KC
0
10
20
30
40
50
60
70
80
90
DECIBELS ABOVE THAT AT CENTER FREQUENCY
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)

GRAPH 9



ITEM MAROON
PLOT OF SIGNAL LEVEL IN DB ABOVE THAT AT THE FREQUENCY MAXIMUM RESPONSE VERSUS THE INPUT FREQUENCY
RECEIVER TUNED TO 1650 KC
MAXIMUM BANDWIDTH TSO C41B
4.6 KC
14.2 KC
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
INPUT SIGNAL FREQUENCY (IN KC ABOVE OR BELOW CENTER FREQUENCY)
0 10 20 30 40 50 60 70 80 90
DECIBELS ABOVE THAT AT CENTER FREQUENCY

2.14 LOOP ANTENNA SENSITIVITY

2.14.1 Objective

To determine the sensitivity of the loop antenna for each test item.

2.14.2 Criteria

When receiving a signal modulated 30 percent by 1000 cps with the loop oriented for maximum signal, the sensitivity measured at the audio output, shall not exceed the following limits for a four-to-one signal-plus-noise-to-noise ratio:

Band	(microvolts/meter)
1	90
2	45
3	30

2.14.3 Method

2.14.3.1 The equipment was tuned to a midband frequency for each of the three bands, and the loop antenna was placed in a signal field, 30-percent modulated with a 1000-cps tone oriented for maximum audio power output. The gain and input signal were adjusted to effect an audio output of approximately 20 percent of rated output, with a 6-db signal-plus-noise-to-noise ratio. The signal field was then removed and the audio output power recorded.

2.14.3.2 The signal and no-signal output power in milliwatts for each band, and the input signal intensity, were recorded.

2.14.4 Results

The results of this test are shown in Table X.

2.14.5 Analysis

None of the sets met the technical requirements. Only Aqua met the requirements of TSO C41b which calls for a sensitivity of 100 microvolts/meter when the above method is employed. Salmon and Maroon did not meet the requirements of the TSO at 400 kc.

TABLE X. LOOP SENSITIVITY

Item	Signal Frequency (KC)	Field Strength (Microvolts/ Meter)	Output Power (Milliwatts)	
			With Signal	No Signal
Salmon	400	120	20	5.0
	650	64	20	5.0
	950	39	20	5.0
Aqua	400	64	50	12.5
	650	64	50	12.5
	950	44	50	12.5
Maroon	400	136	50	12.5
	650	51	50	12.5
	950	34	50	12.5

2.15 COMPASS SENSITIVITY

2.15.1 Objective

To determine the sensitivity of the radio compass portion of each test item.

2.15.2 Criteria

The sensitivity of this radio compass throughout its frequency range shall be such that the maximum variation of five repeated bearings taken on a radio-frequency signal of 25 microvolts per meter, and read on the bearing indicator, shall not exceed two degrees. The absolute sensitivity of the equipment shall be considered at that field strength in microvolts per meter below which the bearings become uncertain, ambiguous, or vary from the "ON-COURSE" bearing by more than 2 degrees.

2.15.3 Method

2.15.3.1 The test signal was applied to the receiver under test, in consonance with the above criteria, while the test item was in the ADF mode. The input was decreased at increments of 2 microvolt/meter.

2.15.3.2 The signal intensity at which the bearing was displaced two degrees was recorded.

2.15.3 Results

The results of this test are shown in Table XI.

2.15.5 Analysis

Salmon and Aqua met the technical requirements only at the two higher frequencies tested. Maroon did not meet them at any frequency tested. The TSO specifies a sensitivity of 70 microvolts per meter when the bearing is displaced from the true bearing by no more than three degrees. All the sets met the TSO requirements.

TABLE XI. FIELD STRENGTH AT WHICH BEARING IS DISPLACED TWO DEGREES

Test Item	Signal Frequency (KC)	Field Strength (Microvolts/Meter)
Salmon	210	38
	440	28
	950	13
	1700	17
Aqua	210	70
	440	48
	950	22
	1700	25
Maroon	210	80
	440	44
	950	30
	1700	100
	210	64*
	1700	62*

*Bearing was displaced three degrees.

(NOTE: Zero bearing is based on 1000 microvolt/meter field strength.)

2.16 COMPASS OPERATING LIFE

2.16.1 Objective

To determine the operating life of the radio compass.

2.16.2 Criterion

This equipment shall be capable of operating without excessive wear or failures due to improper construction or design.

2.16.3 Method

2.16.3.1 A clock was wired to the equipment so that it recorded the total amount of time that the equipment was in operation.

2.16.3.2 Total operational hours at each failure and excessive wear indications, if any, were noted.

2.16.4 Results

Salmon was operated for 63 hours, Aqua for 52 hours, and Maroon for 49 hours. No items failed during operation, and there were no indications of excessive wear.

2.16.5 Analysis

The equipment was not operated long enough to determine whether it met the technical requirements.

SECTION 3. APPENDICES

APPENDIX I -- REFERENCES

1. ARINC Characteristics No. 520A, 24 March 1958, subject: "Airborne VHF Communication Systems."

2. Department of Army Technical Manuals TM 11-5826-204-12 and TM 11-5826-204-35.

3. Department of Army Project No. 1-G-6-50212-D-326-08, "Navigation Air Traffic Regulations" and USATECOM Task 4-4-4316-02, "Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment."

4. U. S. Army Electronics Command (USAECOM) Technical Requirement SCL 8012B, 10 July 1964, "Direction Finder, Automatic Lightweight, Airborne," with Amendment No. 1, 7 August 1964.

5. USAECOM Letter, AMSEL-AV-E, 24 February 1964, subject: "Modernization Program for Omni-Range Receivers, Automatic Direction Finding Equipment and Lightweight HF Aircraft Radio Sets," with one inclosure.

6. U. S. Army Aviation Test Board (USAAVNTBD) Memorandum for Record, 15 April 1964, subject: "Test Requirements Conference, Military Potential (Comparative Evaluation) Test of the OMNI, ADF, and HF Radios, USATECOM Project No. 4-4-4315/4316/4317."

7. USAAVNTBD Memorandum for Record, 29 April 1964, subject: "USAECOM/USATECOM Planning Conference for Military Potential Test of OMNI, ADF, and HF Radios, USATECOM Project No. 4-4-4315/4316/4317."

8. USAECOM Message AMSEL-RD-SRI-5-27, 6 May 1964, subject: "Confirming Telephone Message to Maj Treece on 1 May 1964, Regarding Military Potential Test of OMNI and ADF Receivers."

9. USAAVNTBD Plan of Test, 15 June 1964, subject: "Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment, " as revised 14 September 1964.

10. Radio Technical Commission for Aeronautics, Paper 158-61/DO-111, subject: "Minimum Performance Standards Airborne Radio Receiving and Direction Finding Equipment Operating within the Frequency Range of 200-415 Kilocycles."

11. USAVNTBD Message STEBG-PR, 19 June 1964, subject: "Comparative Evaluation OMNI and ADF Navigation Equipments."

12. Minutes of Conference Held at USAECOM, Fort Monmouth, N. J., 1-2 July 1964, subject: "Evaluation of Commercial Equipment to Replace the AN/ARN-30 OMNI and AN/ARN-59 ADF Radio Sets."

13. USATECOM Message AMSTE-TPAV 7-17, 10 July 1964, subject: "Modernization Program for Automatic Direction Finding Equipment, USATECOM Project No. 4-4-4316."

APPENDIX II -- TEST DIRECTIVE

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HEADQUARTERS
U. S. ARMY TEST AND EVALUATION COMMAND
Aberdeen Proving Ground, Maryland 21005

AMSTE-BG 17 Mar 1964

SUBJECT: Test Directive, USATECOM Project Nr. 4-4-4316( ). Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment

TO: President, U. S. Army Aviation Test Board, Fort Rucker, Alabama 36362
Commanding General, U. S. Army Electronics Proving Ground, Fort Huachuca, Arizona 85613
Commanding Officer, U. S. Army Aviation Test Activity, Edwards Air Force Base, California 93523

1. References:

a. Letter AMSEL-AV-E, HQ USAECOM, dated 24 February 1964, subject: Modernization Program for Omni-Range Receivers, Automatic Direction Finding Equipment and Lightweight HF Aircraft Radio Sets, with 1 Incl (Incl 1).

b. Department of Army Technical Manuals TM-11-5826-204-12 and TM-11-5826-204-35.

c. U. S. Army Arctic Test Board Report, ATB-1357, Arctic Test of AN/ARN-59 Automatic Radio Direction Finder of 2 June 1958.

2. Description of Material: The Automatic Radio Direction Finder is a lightweight airborne radio compass system designed to provide automatically a visual indication of the direction from which an incoming radio frequency signal is being received. It provides for aural reception in the frequency range of 190 to 1750 kilocycles.

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3. Background: The original automatic direction finder (ADF) AN/ARN-42 was found to be unsatisfactory in Army aircraft. As a result of a comparative evaluation of five ADF's the AN/ARN-59 was found most suitable and adopted as standard Army equipment in July 1957. Since the basic system has been sole-source procurement for several years there is the probability that it may not contain the newest design features expected in present day Automatic Direction Finders. Seeking modern equipment for the Army, the Assistant Secretary of the Army has requested that a comparative evaluation be made of available Direction Finders.

4. Test Objectives: To conduct a comparative evaluation of commercial designed Automatic Direction Finders, with the purpose of compiling sufficient test data which may be used as a basis for selection of the most promising or suitable system or systems for Army use.

5. Responsibilities:

a. U.S. Army Aviation Test Board.

(1) Executive Test authority.

(2) Review specifications and available data to determine what test will be required to evaluate Direction Finders.

(3) Prepare and publish a plan of test and report of test.

b. U.S. Army Electronic Proving Ground.

(1) Participating test authority.

(2) Review available engineering test data concerning the equipment to determine what engineering test will be required to evaluate Direction Finders.

(3) Assist as necessary in preparation of test plans and report.

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(4) Conduct engineering test as required.

e. U. S. Army Aviation Test Activity.

(1) Participating test authority.

(2) Assist in preparation of test plan and report.

(3) Review specifications and available test data to determine what flight testing will be needed to qualify equipment.

(4) If required, conduct flight test to establish performance and airworthiness.

6. Coordination: Close coordination will be effected with the U. S. Army Electronics Command, U. S. Army Electronic Research and Development Laboratories, and appropriate USACDC agencies in the planning and execution of the test program.

7. Special Instructions:

a. Direction Finders subjected for test will be supplied by USAECOM. The equipment delivery date is unknown at this time.

b. At completion of tests USAECOM will provide equipment disposition instructions.

c. Cost of individual units will not be considered during the evaluation or mentioned in the final report.

d. USATECOM Project Number assigned:

USAAVNTDD, USATECOM Project Nr. 4-4-4316-01.
USAEPG, USATECOM Project Nr. 4-4-4316-02.
USAATA, USATECOM Project Nr. 4-4-4316-03.

e. This is a Category II test and will be funded by Commodity Command (USAECOM).

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8. Test Plans and Reports:

a. Data for submission of test plan will be established by USAAVNTBD at a coordination conference held by USAECOM at a later date.

b. Test agencies will include with test plan an annex indicating agencies with whom plan was informally coordinated and their comments. If comments were not incorporated in test plan, state in annex reasons why they were not.

c. Test report will be submitted in accordance with USATECOM Regulations 705-2, 705-7, 705-11.

9. Security: This equipment and associated correspondence are unclassified.

FOR THE COMMANDER:

ROGER W. KEMP
Colonel GS
C, Admin Office

5 Incl
1. as
2. Scope of Flight Test for Replacement of AN/ARN-59
3. Evaluation Criteria for ARN-59 Replacement
4. Direction Finder ARN-59
5. Proj Trans Sheets

Copies Furnished:
CG, USAECOM w/o Incl
USAELRDL w/o Incl
USACDC LO, USATECOM w/o Incl
USATECOM ATTN: AMSTE-CP w/o Incl

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HEADQUARTERS
U. S. ARMY TEST AND EVALUATION COMMAND
Aberdeen Proving Ground, Maryland 21005

AMSTE-BG 22 May 1964

SUBJECT: Supplement Test Directive, USATECOM Project No. 4-4-4316( ), Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment

TO: Commanding General, U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona 85613
Commanding Officer, U. S. Army Aviation Test Activity, Edwards Air Force Base, California 93523
President, U. S. Army Aviation Test Board, Fort Rucker, Alabama 36362

1. Reference:

a. Test Directive, USATECOM Project 4-4-4316, dated 17 March 1964, subject as above.

b. Letter, AMSEL-AV-E, subject: Modernization Program for Omni-Range Receivers and Automatic Direction Finding Equipment, dated 14 May 1964.

c. Message, AMSEL-RD-SRI-5-27, dated 6 May 1964.

2. Paragraph 4 of the original test directive, reference a, is amended to include the AN/ARN-59 in the military potential test (Comparative Evaluation) of Automatic Direction Finders. This additional requirement was requested by reference b.

3. The plan of test must include arrangements for testing the AN/ARN-59.

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AMSTE-BG 22 May 1964

SUBJECT: Supplement Test Directive, USATECOM Project No. 4-4-4316( ), Military Potential (Comparative Evaluation) of Automatic Direction Finding Equipment

4. Cost of additional testing will be funded by USAECOM.

FOR THE COMMANDER:

ROBERT A. BAILEY
1st Lt, AGC
Asst Admin Officer

1 Incl
Ltr, AMSEL-AV-E, dtd 14 May 64, w/its Incl

Copies furnished:
CG, USAECOM (w/o Incl)
Dir, USA Elect Lab (w/o Incl)
USACDC LO, USATECOM (w/Incl)

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APPENDIX III -- FINDINGS

S - Salmon
A - Aqua
M - Maroon

TEST	REQUIREMENT	COMPLIANCE SCL 8012B	COMPLIANCE TSO C41b	REMARKS
2.1	Safety	No requirement	No requirement	On Salmon one 28 volt lead-in was improperly insulated.
2.2	Warm-up	No requirement	No requirement	Fast warm-up on all sets.
2.3	Design Features	None comply	No requirement	No failproof devices on sets.
2.4	Volume and Weight	S: Does not comply A, M: Comply	No requirement	Salmon volume was 2 percent greater than the limit volume.
2.5	AGC Constants	All comply	No requirement	
2.6	Stability	All comply	N/A	
2.7	Calibration Accuracy	All comply	N/A	Aqua was noticeably better than the other two.

TEST	REQUIREMENT	COMPLIANCE SCL 8012B	COMPLIANCE TSO C41b	REMARKS
2.8	Power Consumption	S: Does not comply A, M: Comply	No requirement	Salmon power consumption was 5 percent greater than the limit.
2.9	MCW Sensitivity	None comply	All comply	All sets easily meet the TSO limits.
2.10	CW Sensitivity	S: Does not comply A, M: Comply	All comply	The Salmon design output could not be correlated with the inflexible SCL requirements. All sets easily meet the TSO limits.
2.11	Noise Level	S: Complies A, M: Do not comply	No requirement	Aqua design permits a high noise level at high gain.
2.12	Image Rejection	S: Does not comply A, M: Comply	S, M: Do not comply A: Complies	TSO requirement on spurious response includes image rejection and is more stringent than the SCL requirement.
2.13	Receiver Selectivity	S, M: Do not comply A: Complies	None comply	

TEST	REQUIREMENT	COMPLIANCE SCL 8012B	COMPLIANCE TSO C41b	REMARKS
2.14	Loop Sensitivity	None comply	S, M: Do not comply A: Complies	
2.15	Compass Sensitivity	None comply	All comply	Salmon and Aqua easily meet the TSO limits.
2.16	Operating Life	Compliance not determined	N/A	Tests were not run long enough to determine compliance. No failures occured.

PART B

USAHEL REPORT

(Not available at this time;
will be submitted at a later date.)

SECTION 4

APPENDICES

APPENDIX I

ADF MAINTENANCE TEST DATA

1. Aqua.

Date	Equipment Hours	Discrepancy	Corrective Action	Man-Hours Org.	Man-Hours Field	Remarks
27 Oct	33.7	Aircraft 710--ADF #2 inoperative.	Replaced transistor (Q903) & Diode (CR 903) in ADF Amplifier, Serial No. 1145.	1.1	2.1	Failure of Q903 and CR903 caused the loss of the regulated 10 v.d.c. power source resulting in system failure.
2 Dec	93.6	Aircraft 710--ADF #2 Goniometer inoperative.	Resoldered RF connections on J-3003 on Goniometer, Serial No. 2006.	1.4	1.7	Bench checks indicated a loose connection in the RF input wiring. A close inspection failed to locate a positive loose connection. The complete connector was resoldered and problem was eliminated.

2. Maroon.

Date	Equipment Hours	Discrepancy	Corrective Action	Man-Hours Org.	Man-Hours Field	Remarks
9 Nov	36.9	Aircraft 360. Indicator hunts continuously, weak response.	None.	1.6	2.2	System was removed from A/C and bench checked. The system met all specifications except for audio output settings. The audio output was adjusted and system was reinstalled for further testing.

3. Salmon.

Date	Equipment Hours	Discrepancy	Corrective Action	Man-Hours Org.	Man-Hours Field	Remarks
4 Nov	21.6	Aircraft 430. ADF needle sluggish and hunts excessively.	Replaced transistor (Q-17) in receiver, Serial No. 227.	0.8	1.8	The failure of transistor (Q-17) loop servo amplifier, caused an insufficient 110 c.p.s. signal on the control winding of the loop servo motor resulting in sluggish loop operation.

Date	Equipment Hours	Discrepancy	Corrective Action	Man-Hours Org.	Man-Hours Field	Remarks
1 Dec	35.3	Aircraft 1430. Unable to control audio (RF Gain) in antenna position.	Cleaned wafer switch (S-302A) in control panel, Serial No. 859.	0.4	2.5	Trouble shooting of control head isolated problem to high resistance short between contacts on wafer switch. Control panel was disassembled for access. Evidence of foreign matter was found. The wafer switch was cleaned and problem was eliminated.

APPENDIX II

DEFICIENCIES AND SHORTCOMINGS

Definitions of these terms, according to USATECOM Regulation 705-7, are quoted herein for information:

"Deficiencies: Deficiencies are defects or malfunctions discovered during the life cycle of an equipment that constitute a safety hazard to personnel, will result in serious damage to the equipment if operation is continued; or indicate improper design or other cause, which seriously impairs the equipment's operational capability. A deficiency normally disables or immobilizes the equipment; or if occurring during test phases, will serve as a bar to type classification (AR 320-5)."

"Shortcomings: Shortcomings are imperfections or malfunctions occurring during the life cycle of an equipment which should be reported and which must be corrected to increase the efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product. If occurring during test phases, the shortcoming should be corrected if it can be done without unduly complicating the item or inducing another undesirable characteristic, such as increased cost, weight, etc. (AR 320-5)."

A. DEFICIENCIES. The following deficiencies were discovered during the human engineering portion of the military potential test unless otherwise noted:

1. Aqua.

Deficiency	Suggested Corrective Action	Remarks
a. The toggle switch for loop control on the ADF tuner control panel was too small.	Replace toggle switch with larger size.	Applicable standards are contained in the USAHEL report.
b. The toggle switch for BFO (Beat Frequency Oscillator) control on the ADF	Replace toggle switch with larger size.	Applicable standards are contained in the USAHEL report.

Deficiency	Suggested Corrective Action	Remarks
tuner control panel was too small.		
c. The index line on the frequency dial was difficult to see at night.	Improve conspicuousness of the frequency dial at night.	Applicable standards are contained in the USAHEL report.
d. Speech intelligibility was below the "normal" category.	Improve the speech intelligibility to at least the normal category.	Applicable standards are contained in the USAHEL report.

2. Maroon.

Deficiency	Suggested Corrective Action	Remarks
a. The toggle switch for loop control on the radio receiver control panel was too small.	Replace toggle switch with larger size.	Applicable standards are contained in the USAHEL report.
b. The toggle switch for BFO control on the radio receiver control panel was too small.	Replace toggle switch with larger size.	Applicable standards are contained in the USAHEL report.
c. The frequency dial was masked due to small size of the window.	Increase size of window.	Applicable standards are contained in the USAHEL report.
d. The tuning meter was too small and was partially masked.	Replace with larger meter.	Applicable standards are contained in the USAHEL report.
e. The digital frequency readout did	Undetermined.	This deficiency was discovered during

Deficiency	Suggested Corrective Action	Remarks
not align accurately with the selected frequency.		USAAVNTBD tests.
f. Speech intelligibility was below the "normal" category.	Improve the speech intelligibility to at least the normal category.	Applicable standards are contained in the USAHEL report.
g. System sensitivity was too low.	Undetermined.	This deficiency was discovered during USAAVNTBD tests.
h. The loop antenna did not meet the FAA TSO applicable in the area of loop antenna sensitivity. This resulted in a degradation of performance in flight, especially in "loop" mode.	Undetermined.	This deficiency was discovered during USAAVNTBD tests.

3. Salmon.

Deficiency	Suggested Corrective Action	Remarks
a. On the ADF control unit, the frequency dial index markings were nonlinear.	Replace with linear markings in kilocycles.	Applicable standards are contained in the USAHEL report.
b. The frequency dial index was marked in megacycles rather than kilocycles.	Replace with linear markings in kilocycles.	Applicable standards are contained in the USAHEL report.

Deficiency	Suggested Corrective Action	Remarks
c. The BFO switch was too small.	Replace with larger switch.	Applicable standards are contained in the USAHEL report.
d. The knob markings were not illuminated.	Illuminate knob markings.	Applicable standards are contained in the USAHEL report.

B. SHORTCOMINGS. Listed below are shortcomings discovered during the USAAVNTBD evaluation. See parts A and B of section 3 for shortcomings discovered during the USAHEL and USAEPG tests.

1. Aqua.

Shortcoming	Suggested Corrective Action	Remarks
a. No fail-safe device was provided on system.	None.	The intent of the SCL is not clear in this case. The best known in-flight reliability check for ADF is to slew the loop left or right while in the compass mode; if the needle returns to the station position, it is an indication of proper operation.

Shortcoming	Suggested Corrective Action	Remarks
b. System did not meet SCL requirement for noise level. *	None.	
c. Slew rate on manual loop control switch mode was too fast.	Change rate of response.	This rapid rate of slew resulted in over-sensitivity, and made manual loop approaches difficult to accomplish.

2. Maroon.

Shortcoming	Suggested Corrective Action	Remarks
a. No fail-safe device was provided on the system.	None.	The intent of the SCL is not clear in this case. The best known in-flight reliability check for ADF is to slew the loop left or right while in the compass mode; if the needle returns to the station position, it is an indication of proper operation.
b. System did not meet SCL requirement for noise level. *	None.	

*These results of the evaluation are not considered conclusive because the technical requirements specified the use of impedances, etc., in the bench tests which were not compatible with the systems tested.

Shortcoming	Suggested Corrective Action	Remarks
c. System was adversely affected by thunderstorm activity to such an extent that it was at times rendered unusable as an enroute navigation aid.	None.	All ADF's are adversely affected by thunderstorms to some extent; Maroon was affected much worse than the other systems tested.
d. Volume could not be turned all the way down without turning set off.	Replace volume control with one with lower minimum resistance.	The audio feed-through, with the receiver volume control at minimum, is sufficiently high to cause pilot discomfort and to interfere with operation of other navigation equipment.
e. Set was very noisy on "loop" position.	None.	The loop antenna used with this system would not pass TSO. The results in flight validate the apparent shortcoming.
f. Set was "noisy," with CW, RTTY signals, etc., coming through on all bands.	None.	The noise was noticeable and degraded the performance of the ADF considerably.

3. Salmon.

Shortcoming	Suggested Corrective Action	Remarks
a. No fail-safe device was provided on the system.	None.	The intent of the SCL is not clear in this case. The best known in-flight reliability check for ADF is to slew the loop left or right while in the compass mode; if the needle returns to the station position, it is an indication of proper operation.
b. System did not meet SCL or TSO requirement on Receiver Selectivity.*	None.	
c. System did not meet SCL or TSO requirement on loop sensitivity.*	None.	
d. Volume was two percent greater than 750-cubic inch limit.	None.	This apparent shortcoming is based on measurements which cannot be exact; indentations, wasted space, etc., cannot be precisely

*These results of the evaluation are not considered conclusive because the technical requirements specified the use of impedances, etc., in the bench tests which were not compatible with the systems tested.

Shortcoming	Suggested Corrective Action	Remarks
		measured. The measured volume of this set is 767 cubic inches.
e. Power consumption was five percent greater than limit.	None.	The set used 1.05 amperes at 26.5 v.d.c.; the limit was 1 ampere.
f. System did not meet SCL or TSO requirement on Image Rejection.*	None.	

*These results of the evaluation are not considered conclusive because the technical requirements specified the use of impedances, etc., in the bench tests which were not compatible with the systems tested.

APPENDIX III

DETAILED DESCRIPTIONS OF TEST ADF EQUIPMENT

1. Aqua. The Aqua ADF system frequency coverage is 190 kc. to 1750 kc. on three bands. Frequency tuning is accomplished by a hand-operated crank and indicated by a rotating tape. The system weighs 14 pounds 7 ounces and consists of the following components:

a. ADF Tuner. The ADF tuner is mounted directly in the instrument panel, contains the RF circuitry for the receiver, and is completely transistorized. The required panel space is 5 3/4 inches wide x 3 3/4 inches high. The tuner is 7 1/4 inches deep and weighs 4 pounds 4 ounces. The tuner panel has manually-adjustable controls for selecting the following:

(1) Mode of operation.

(2) Frequency.

(3) Loop rotation.

(4) Voice or CW.

(5) Volume.

b. ADF Amplifier. The ADF amplifier is a completely transistorized intermediate-frequency and audio-frequency amplifier. The amplifier is 2 1/2 inches wide x 3 7/16 inches high x 13 3/8 inches long and weighs 3 pounds 13 ounces.

c. ADF Gonio/Indicator. The Goniometer/Indicator provides visual indications of the relative bearing of a radio transmitter with respect to the aircraft. It also furnishes synchro signals for the operation of a remotely located radio magnetic indicator (RMI). It is contained in a standard 3 1/4 inch aircraft instrument case and weighs 1 pound 15 ounces.

d. ADF Antenna Coupler. The ADF antenna coupler is an impedance matching device use to couple the sense antenna to the tuner. All components are within an aluminum container measuring 1 1/2 inches x 1 1/2 inches x 2 1/4 inches and weighs 3 ounces.

e. ADF Loop Antenna. The ADF loop antenna is a lightweight fixed type, sealed in a fiber glass shell. The shell is 16 7/8 inches long x 9 7/8 inches wide x 15/16 inch thick and weighs 3 pounds and 7 ounces.

f. Mounting.

(1) A shock mount is provided for aircraft installation of the amplifier. The mount measures 16 1/2 inches long x 2 9/16 inches wide x 4 1/2 inches high and weighs 13 ounces. The amplifier is secured by one thumbscrew for rapid replacement.

(2) The receiver unit mounts directly into the instrument panel, utilizing panel space 5 3/4 inches wide x 3 3/4 inches high.

2. Maroon. The Maroon ADF system frequency coverage is 100 kc. to 3,000 kc. on four bands. Frequency tuning is accomplished by a hand-operated crank and indicated by digital readout. The system weighs 18 pounds 13 ounces and consists of the following components:

a. Radio Receiver. The ADF receiver is mounted directly into the instrument panel, contains all of the RF and IF amplifier circuits, and is completely transistorized. The required panel space is 5 3/4 inches wide x 3 3/4 inches high. The receiver unit is 7 1/2 inches deep and weighs 7 pounds 7 ounces. A meter for indicating signal strength is included in the panel. The receiver panel has manually-adjustable controls for selecting:

(1) Mode of operation.

(2) Frequency.

(3) Loop rotation.

(4) Voice or CW.

(5) Volume.

(6) Over-ride (for use when two receiver positions are used).

b. Synchro Signal Amplifier. The amplifier consists of the following four plug-in modules, a gearing assembly, and the main chassis:

(1) 155-c.p.s. power amplifier.

(2) 155-c.p.s. oscillator and navigation amplifier.

(3) Audio amplifier.

(4) Transient eliminator and voltage regulator.

This unit furnishes synchro signals for the operation of a remotely located RMI. The amplifier is 6 inches high x 2 1/2 inches wide x 12 7/16 inches deep and weighs 4 pounds 12 ounces.

c. ADF Indicator. A standard ID-637/ARN is furnished (1 pound 4 ounces).

d. ADF Loop Antenna. The ADF loop antenna is a lightweight fixed-type sealed in a casting of urethane. The casting is 6 1/8 inches square x 3 1/8 inches high and weighs 3 pounds 7 ounces.

e. Mounting. A shock mount is provided for aircraft installation of the synchro signal amplifier. The mounting contains a filter to minimize RF interference. The mounting is 3 7/8 inches high x 3 7/32 inches wide x 13 1/2 inches deep, and weighs 1 pound 15 ounces. The amplifier is secured by one thumbscrew for rapid replacement.

3. Salmon. The Salmon ADF frequency coverage is 190 kc. to 1750 kc. on three bands. Frequency tuning is accomplished by a hand-operated knob and indicated by a translucent plastic dial. The system weighs 18 pounds and 4 ounces and consists of the following components:

a. ADF Control Unit. The ADF control unit which is mounted directly into the instrument panel requires panel space 5 3/4 inches wide x 2 5/8 inches high. The unit is 4 15/16 inches deep and weighs 1 pound 12 ounces. The control unit contains all the manually operated switches used to remotely control the ADF receiver as well as a meter for indicating signal strength. The control unit has manually-adjustable controls for selecting:

(1) Mode of operation (includes power on switch).

(2) Frequency.

(3) Loop rotation.

(4) Voice or CW.

(5) Volume.

b. ADF Receiver. The ADF receiver is the principal unit of the ADF system. It contains all of the RF, IF, and AF circuitry and components and furnishes synchro signals for the operation of a remotely located RMI. The receiver is completely transistorized. The receiver unit is 7 5/8 inches high x 2 1/4 inches wide x 14 5/8 inches deep and weighs 9 pounds 12 ounces.

c. ADF Bearing Indicator. A standard ID-673/ARN is furnished with this set (1 pound 3 ounces).

d. ADF Sense Antenna Coupler. The ADF sense antenna coupler matches the impedance of the sense antenna and ADF receiver. The coupler measures 2 9/16 inches x 1 5/16 inches x 2 7/32 inches and weighs 8 ounces. It is used in bench test applications and some aircraft installations.

e. ADF Loop Antenna. The ADF loop antenna is a lightweight fixed-type, sealed unit. It measures 16 inches long x 12 inches wide x 7/8 inch thick and weighs 3 pounds 13 ounces.

f. Mounting. A shock mount is provided for aircraft installation of the receiver. The mount measures 16 inches long x 3 5/16 inches wide x 9 1/16 inches high and weighs 1 pound 4 ounces. The receiver is secured by one thumbscrew for rapid replacement.

APPENDIX IV

COORDINATION

The following agencies participated in the review of the final report:

US Army Combat Developments Command Aviation Agency

US Army Aviation School

US Army Electronics Proving Ground

APPENDIX V - DISTRIBUTION LIST

Agency	No. Copies
Commanding General US Army Test and Evaluation Command ATTN: AMSTE-BG Aberdeen Proving Ground, Maryland 21005	2
Commanding General US Army Electronics Command ATTN: AMSEL-AV-G Fort Monmouth, New Jersey 07703	25

AD______________________________ Accession No. ______________

US Army Aviation Test Board, Fort Rucker, Alabama. Report of USATECOM Project No. 4-4-4316-01, Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment, 3 February 1965, DA Project No. 1G641203D526, 120 pp., 3 illus. FOR OFFICIAL USE ONLY. It was concluded that Salmon is the most promising and suitable system for Army use, Aqua the next most suitable, and Maroon the least suitable; that the deficiencies must be corrected before any system is acceptable for Army use; that available technical requirements were not a satisfactory standard for technical evaluation of these systems; and that correction of shortcomings would enhance the suitability of each system for Army use. It was recommended that the deficiencies be corrected prior to acceptance of any system; the system selected undergo a complete engineering/service test prior to acceptance as a standard item; and the technical requirements be rewritten prior to engineering/service test.

AD______________________________ Accession No. ______________

US Army Aviation Test Board, Fort Rucker, Alabama. Report of USATECOM Project No. 4-4-4316-01, Military Potential Test (Comparative Evaluation) of Automatic Direction Finding Equipment, 3 February 1965, DA Project No. 1G641203D526, 120 pp., 3 illus. FOR OFFICIAL USE ONLY. It was concluded that Salmon is the most promising and suitable system for Army use, Aqua the next most suitable, and Maroon the least suitable; that the deficiencies must be corrected before any system is acceptable for Army use; that available technical requirements were not a satisfactory standard for technical evaluation of these systems; and that correction of shortcomings would enhance the suitability of each system for Army use. It was recommended that the deficiencies be corrected prior to acceptance of any system; the system selected undergo a complete engineering/service test prior to acceptance as a standard item; and the technical requirements be rewritten prior to engineering/service test.

CODE SHEET

This code sheet will be removed from the report when loaned or otherwise distributed outside the Department of Defense.

Code	Manufacturer
Aqua	Bendix Corporation
Maroon	Aircraft Radio Corporation
Salmon	Collins Radio Corporation